PERFORMANCE STUDY & EVALUATION OF ELECTRICAL PARAMETER OF DRAGLINE IN OPEN CAST MINES

THIS THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

MINING ENGINEERING

BY

ATMA RAM SAHU

213MN1498

Under the guidance of

PROF. H.K.NAIK

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLGY

ROURKELA-769008

2014 -15

Dedicated to my teacher’s & family

DEPARTMENT OF MINING ENGINEERING

NATIONAL INSTITUTE OF TECHNOLGY

ROURKELA-769008

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CERTIFICATE

This is to certify that the thesis entitled **"Performance Study & Evaluation of Electrical Parameter of Dragline in Open Cast mines"** submitted by **Mr. Atma Ram Sahu** in partial fulfillment of the requirements for the award of Master of Technology degree in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree

Date;

Prof. H.K.NAIK

Head of department of Mining Engineering, National Institute of Technology Rourkela – 769008

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At last, my sincere thanks to all my friends who have patiently extended all sorts of helps for accomplishing this assignment.

Date : **Atma Ram Sahu**

ABSTRACT

Draglines are the most expensive piece of excavating equipment at the mine site and it's operated safely, efficiently and economically. In order to achieve high production and productivity of heavy earth moving machine in opencast mines, it is necessary to have high % availability and % utilization of equipment. The study also propounds the importance of appraisal of dragline productivity parameters, such as, swing angle, availability, seating position, cycle time, utilization, etc., in the field scale. In this contest, calculation of operating cost of dragline operation in various methods has been done and compared critically on case study basis. Principally, it will serve as a guide to the method employed in determining the operating cost in various methods. Draglines are versatile and provide a low cost mining method.

Each dragline that is considered for an AC Electrical upgrade will be fully analyzed to determine the machines maximum potential productivity increases. The assessment will include review of current dragline productivity practices, installed electrical capability and additional mechanical enhancements that could be included, such as increased suspended load, which will allow us to take full advantage of the AC IGBT/AFE system and BI 348 motor with its increased capability and still operate the machine within Bucyrus recommended criteria. The AC IGBT/AFE System has a fully integrated onboard computer package that allows complete access to the drive application software and PLC software and chopper drive use in regenerative braking. It is called access direct which will be discussed.

Surface mining ventures like **Amlori open cast project of NCL, Singrauli (M.P.)** with coal production targets (about 20 million tons per annum) this is possible to remove large volume of overburden in shortest possible time. Northern Coalfields Limited (NCL) is the only subsidiary company of CIL, where the entire coal production (98 %) is mined by opencast mining method and 40 % of the large volume of overburden excavation is done with the help of larger walking draglines. Draglines are used in all the mines of NCL except in Gorbi, Jhingurda, and Kakri. NCL was formed by November 1985 as a subsidiary company of CIL. The mine's output is totally dependent on the dragline's parameters and different drive technology, PLC technology to increase the production of mines. In this thesis an attempt is made to discuss the different parameter and how to increase the efficiency, Utilization, Availability, production rate of dragline.

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Chapter 1

INTRODUCTION

1. Introduction

1.1 Dragline mining

A **dragline excavator** is a piece of heavy equipment used in removal of overburden in surface mining. Draglines used in civil engineering for the construction of port, road, pond, and canal dredging. Mining is one of the most important activities to extract resource from the earth's crust. Mining is divided into two main parts.

- Underground mining
- Surface mining.

In open cast mines draglines are used to excavate a maximum of 50 to 80m of overburden to reach dump height of about 39m (Ref: collected data from NCL, Singrauli, Amlori project). Demand of energy is continuously increasing in India, coal which is full fill the requirement of fuel which spread raw material (fossil fuels) throughout the earth's crust. A most considerable part of coal is produced by open cast mining methods.

Fig: 1 Schematic diagram of a Dragline

Walking dragline is a principal tool in open cast mining operations which removes large amounts of overburden material in order to expose valuable minerals to be mine in depth of earth crust. In order to increase the efficiency of such machines used in new technology of drive system with PLC controller and larger in size of bucket, boom length and in their load-carrying capabilities. In order to improve dynamic response time and decrease digging cycle time, digging time and overall performance have to be approve by increased the workload on the operator and has probably made the operator more susceptible to error.

1.2. Dragline used in India

Coal producers have already tried to open up big surface coalmines in various coalfields by used in dragline to remove over burden. Indian mining industry has contributed significantly amount of coal to make the nation self-sufficient in coal for systems to remove large volume of overburden in shortest possible time by used large walking dragline.

Draglines used in India for overburden stripping because of their fast controlling, required less manpower, production of coal per unit cost is less as compared to other method of removal of over burden, high production rate and flexibility. Hence, the Indian open cast coal mining has been used dragline mining for removal of overburden in most of large sized coal mines to increase the high rate production.

Dragline operation of India

Table: 1.1 Dragline operation of India

	Mine	30/70	24/96	20/90	15/90	10/70	10/60	11.5/45	6/45	5/45	4/45	6.9/70	Total
NCL	Amlohri		1										1
	Bina		2			2							4
	Dudhichua		4										4
	Jayant		3		1								4
	Khadia			2									2
	NIgahi		2	2									4
			12	4	1	2							19
SECL	Bisrampur	2											2
	Chirmiri					1							1
	Dhanpuri			1		1							2
	Jamuna					1				1			2
	Kurasia					1							1
	Rajnagar					1							1
	SUB TOTAL	2		1		5				1			9
MCL	Balanda							1					1
	Belpahar					1							1
	Bharatpur			1									1
	Hingula										1		1
	Lajkura					1	1						2
	Samleshwaril					1							1
				1		3	1	1			1		7

	Mine	30/70	24/96	20/90	15/90	10/70	10/60	11.5/45	6/45	5/45	4/45	6.9/70	Total
WCL	Ghugus		1										1
	Sasti			1									1
	Umrer				1							1	2
	SUB TOTAL		1	1	1							1	4
BCCL	Block-II		1										1
	S.Tisra								1				1
			1						1				2
ECL	Sonpur Bazari		1										1
SCCL	Ramagundam-1		1										1
	Ramagundam-3	1											1
		1	1										2
INDIA		3	16	7	2	10	1	1	1	1	1	1	44

Present Dragline of India coal mines

Table: 1.2 Present Dragline of India coal mines

COMPANY	SPECIFICATION	MODCIL	MODEL	LOCATION	DATE OF COMMI SN.
SECL	11.5/45	PAGE 734 E		KURASIA	1961
SECL	6/45	P&H 1855		KURASIA	1961
MCL	6/45	P&H 1855		BALANDA	1961
MCL	11.5/45	PAGE WKG.	PAGE WALKING	BALANDA	15-03-62
SECL	30/70	M 7800	M 7800	BISRAMPUR	30-11-64
WCL	6.88	M 7400	DRA 7400	UMRER	18-05-65
SECL	30/70	M 7800	M 7800	BISRAMPUR	10-08-67
WCL	4/45	E S H 4/45	E S H 4/45	UMRER	1967
MCL	4/45	E S H 4/45	E S H 4/45	HINGULA	15-10-69
MCL	10/60	E S H 10/60	E S H 10/60	LAJKURA	12-01-70
SECL	5/45	E S H 5/45	5/45	JAMUNA	05-06-77
NCL	10/70	E S H 10/70		BINA	15-05-78
WCL	15/90	E S H 15/90	DRA 15/90	UMRER	15-06-78
NCL	15/90	E S H 15/90		JAYANT	01-04-79
NCL	10/70	E S H 10/70		BINA	08-05-79
SECL	10/70	E S H 10/70	10/70	CHIRIMIRI	25-03-81
SECL	10/70	E S H 10/70	10/70	KURASIA	26-09-81
NCL	24/96	24/96		JAYANT	01-10-83
SECL	10/70	E S H 10/70	10/70	RAJNAGAR	30-10-84
NCL	24/96	24/96		JAYANT	02-03-85
NCL	24/96	24/96		BINA	10-03-86
SECL	10/70	E S H 10/70	10/70	DHANPURI	18-02-87
NCL	24/96	24/96		BINA	06-04-87
BCCL	24/96	24/96	W2000	BLOCK-II	04-12-88
SECL	10/70	E S H 10/70	10/70	JAMUNA	24-12-88
NCL	24/96	24/96		JAYANT	08-03-89
MCL	20/90	E S H 20/90	E S H 20/90	BHARATPUR	01-05-89
BCCL	6.5/45	E S H 6.5/45	ESH6.5/45	S.TISRA	08-12-89

MCL	10/70	E S H 10/70	E S H 10/70	LAJKURA	26-02-90
SECL	20/90	E S H 20/90	20/90	DHANPURI	10-04-90
MCL	10/70	E S H 10/70	E S H 10/70	BELPAHAR	10-08-90
NCL	24/96	24/96		DUDHICHUA	01-09-91
WCL	24/96	24/96	DRA WA2000	GHUGHUS	08-12-91
NCL	20/90	E S H 20/90		NIGAHI	01-04-92
MCL	10/70	E S H 10/70	E S H 10/70	SAMLESHWARI	01-07-92
WCL	20/90	E S H 20/90	DRA 20/90	SASTI	16-07-92
NCL	20/90	E S H 20/90		KHADIA	02-10-92
NCL	24/96	24/96		AMLOHRI	01-07-93
NCL	20/90	E S H 20/90		NIGAHI	25-03-94
NCL	20/90	E S H 20/90		KHADIA	26-06-95
NCL	24/96	24/96		DUDHICHUA	15-08-95
ECL		M7820-50	7820-50	SONPUR BAZARI	09-11-96
NCL	24/96	24/96		DUDHICHUA	26-12-99
NCL	24/96	24/96		DUDHICHUA	10-10-01
NCL	24/96	24/96		NIGAHI	13-04-02
NCL	24/96	24/96		NIGAHI	15-04-03
SCCL	24/96	24/96	HEC-W2000	RAMAGUNDAM OC 1	
SCCL			BEML -7820	RAMAGUNDAM OC 3	

1.3 Objectives

(a) The goal of this thesis to evaluate the electrical parameter of dragline and calculate the projected output, cycle time calculation of ownership, operating cost and cost per ton of coal exposed of dragline by the combination of various parameters during field study.

(b) Critical review and evaluation of different parameter of dragline, drive technology, PLC technology, electrical parameter, mechanical design, trailing cable used in dragline

1.4 Specific objectives

1. Literature review
    - Different stage of dragline upgrades
    - Drive System of working of dragline and methods of working of dragline
    - Draglines used in Indian coal mines
2. Drive technology of dragline used in open cost mine.
3. PLC technology of dragline
4. Calculation of % availability, % utilization, annual output, ownership, operating cost and cost per ton of coal exposed by dragline.

5. Trailing Cable.
6. Study of stress distribution in a dragline bucket using finite element analysis (FEA)

1.5 Methodology

The specific objectives were achieved by following methods:

1. Study of available literature and different stage of upgrades of different parameter of dragline

2. Visit to mines NCL Sinngrauli project Amlori abhimantu dragline for collecting data.

3. Calculation of different parameter of dragline.
4. Stress distribution of dragline bucket is investigated using FEA

Chapter 02

LITERATURE REVIEW OF DRAGLINE

2.1. History of dragline evolutions

- 1904: W. Page of Page Schnabel used in Chicago canal.
- 1910: Bucyrus International Company introducing first crawler mounted dragline.
- 1912: Page Engineering Company providing draglines with mobility.
- 1939: Marion Steam Shovel Dredge Company builds its first walking mechanism.

2.2 DC to AC Evolution in Mining (20th Century)

- 1920's Ward-Leonard Generator DC drives introduced on Shovels & Draglines.
- 1970's General Industry starts migration to AC drives.
- 1976 Bucyrus forms alliance with Siemens for AC drive development.
- 1980 Bucyrus introduces analog SCR AC drives - shovels and small draglines.
- 1989-1998 Bucyrus introduces digital GTO AC drives - shove small draglines and large dragline swing.
- 1999 Bucyrus & Siemens design next generation of AC Drives utilizing AC IGBT/AFE technology - shovels and large dragline swing
- 1999-2006 Bucyrus sells AC IGBT/AFE drives for 495BII, HD, HR & HF shovels and large dragline swing - 2570WS.
- 2003 Bucyrus & Siemens develop first all AC IGBT/AFE gearless drive system using Synchronous Motors for Hoist and Drag - large draglines.
- 2004 Bucyrus sells first AC IGBT/AFE gearless 8750 dragline *(start up due late 2006).*
- 2006 Bucyrus & Siemens develop new AC drive motor *(same motor for all motions - BI 348)* in conjunction with existing AC IGBT/AFE technology for use with conventional gearing - small and large draglines.
- 2006 Bucyrus sells first AC IGBT/AFE Conventional 8750 Dragline to Lake Lindsay in Australia

2.3 Programmable Controller Development

- 1968 Programmable concept develop
- 1969 Hardware CPU controller, with logic instructions, 1 K of memory and 128 I/O points.
- 1974 Use of several (multi) processors within a PLC - timers and counters; arithmetic Operations; 12 K of memory and 1024 I/O points.
- 1976 Remote input/output systems introduced
- 1977 Microprocessors - based PLC introduced
- 1983 Low - cost small PLC's introduced
- 1985 Networking of all levels of PLC, computer and machine using SCADA software.

2.4 NCL Singrauli

NCL is the only subsidiary company of Coal India limited, where the all most coal production (98 %) is mined by surface mining method. NCL used in dragline to remove about 40% of the large volume of over burden is removed. NCL was formed by November 1985 as a subsidiary company of CIL. Head quarter of Northern Coalfields Limited located in Singrauli. The area of coal field is about 2202 km square and this region is called **Capital Power of India**. The coal field divided into two basins.

1. Singrauli main basin (1890 km square)
2. Mohar sub-basin (132 km square)

The most part of the Moher sub-basin lies in the Singrauli district of (M.P.) and a small part of the Moher sub-basin lies in the Sonebhadra district of (U.P.). The coal supplies from NCL have made it possible to produce more than 11000 MW of electricity from power plants of NTPC and Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd (UPRVUNL) and Renupower division of M/s. Hindalco Industries. The region is called the **Capital power of India**. The total capacity of power generation of these power plants is 13295 MW and NCL is fully prepared to meet the increased demand of coal for the purpose. In addition, Northen coal field limited supplies coal to power plants of Rajasthan Rajya Vidyut Utpadan Nigam, Haryana Power Generation Corporation Limited and Delhi Vidyut Board (DVB).

Present status of Draglines in NCL

Table 2.1 Present Draglines of NCL Singrauli

SNo	Project	Model	Name	DOC	Prog Whr
1	Amlohri	24/96	Akshay	01.07.93	118232
2	Bina	24/96	Gaurav	10.03.86	162914
3		24/96	Saurav	06.04.87	160960
4	Dudhichua	24/96	Pawan	10.10.01	67431
5		24/96	Jyoti	01.09.91	108822
6		24/96	Vindhya	15.08.95	99856
7		24/96	Jwala	26.12.99	70857
8	Jayant	24/96	Saraswati	08.03.89	160564
9		24/96	Ganga	01.10.83	195824
10		24/96	Yamuna	02.03.85	183936
11	Nigahi	24/96	Krishna	13.04.02	68902
12		2/96	Balram	15.04.03	61424

13	Nigahi	20/90	Bajrang	01.04.92	123682
14		20/90	Matang	25.03.94	120829
15	Khadia	10/90	Baijnath	02.10.92	123837
16		20/90	Vishwanath	26.06.95	113101
17	Jayant	15/90	Vijay	01.04.79	193896
18	Bina	10/70	Ram	15.05.78	201560
19		10/70	Shyam	08.05.79	206171

Dragline used in NCL having basin.

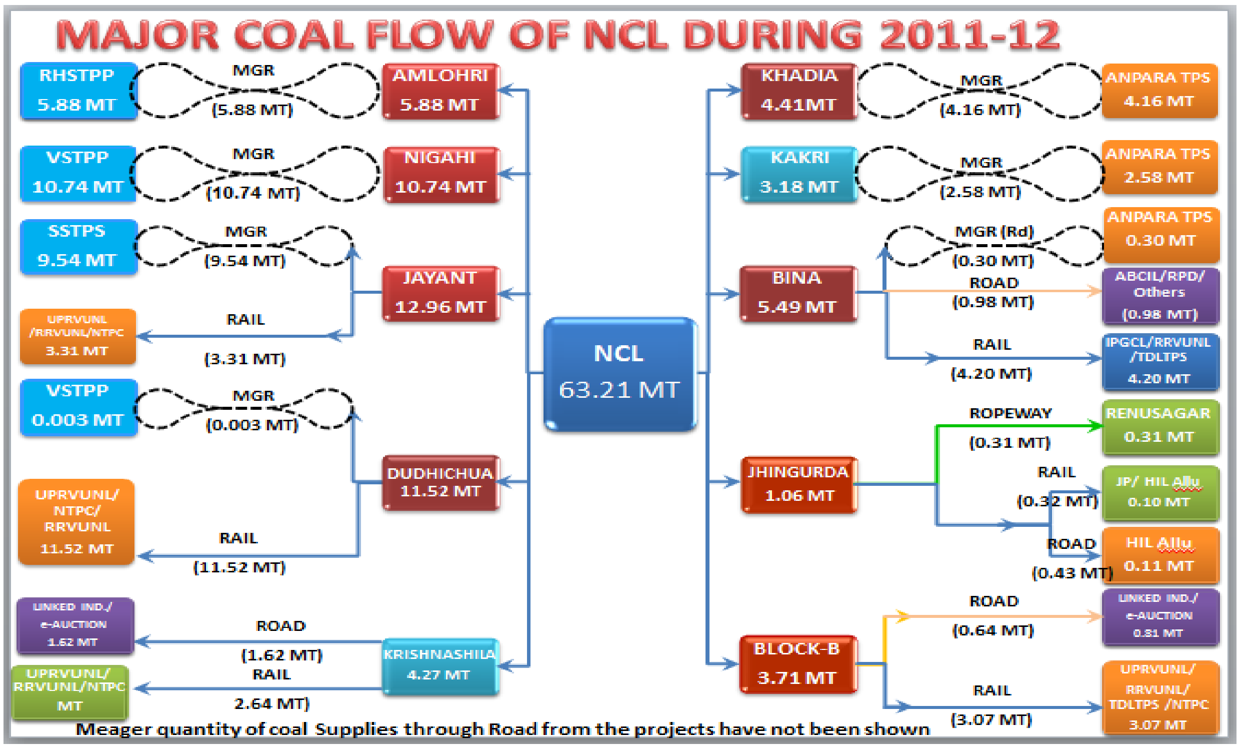
Table 2.2 Dragline used in NCL having basin

	Project	Capacity of Dragline	No. of Draglines	
1.	Amlori	24x96	1	MOHER-SUB BASIN, SIngrauli Coalfield. The NCL is presently working in Moher sub-basin of Singrauli coalfield. The basin has three seams in most of its area. The upper seams are 8-10 m thick with a parting of about 40 m in between. The lowermost seam is 16-22 m thick and has a parting of about 40 m between it and the second seam. The seams are flat (about 2 degree gradient). Upper seams are worked by shovel dumper combination and draglines are used only for removal of OB above the bottom most seam. When all the three seams are worked in any project of this sub-basin, the percentage of OB handled by dragline will only be 20-25 % of the total OB
2.	Bina	10x70 - 2 24x96 - 2	4	
3.	Dudichua	24x96	2	
4.	Jayant	15x90 - 1 24x96 - 3	4	
5.	Khadia	20x90	2	
6.	Nigahi	20x90	2	
Total for NCL			15	

2.5 NCL Singrauli coal mines

- **Amlori project**
- **Jayant project**
- **Bina**
- **Dudichua**

- **Jhangurdah**
- **Kakri**
- **Khadia**
- **Nigahi**
- **Krishnashila**
- **CWS project**
- **IWSS project**
- **Gorbi block-B**
- **NSC**



Fig; 2.1 Coal flow of NCL Singrauli in 2011-12

2.5.1 **JAYANT PROJECT (10 MTY) NCL Singrauli**

The project is located in south-central part of the Moher Sub-basin of Singrauli Colafield. The area geographically lies between latitudes of 24 0 9 ' 50 " to 24 0 11 ' 25" North and longitudes 82 0 38' 25 " to 82 0 41' 42 " East and comprise Gondwana rocks covering about 312 sq km of which coal bearing Barakars occupy 225 sq km. The project has achieved highest ever composite production of 31.68 M. Cum in the year 2010-11, which is not only highest in NCL but also in Coal India Limited.

MINING AND GEOLOGICAL CONDITION

- OB thickness: - : 10m (at outcrop) 180m (N-E part)
- Av. Stripping ratio : 2:60
- Over Burden : 90% is medium and coarse grained sand stone
- Capital cost as per RCE : Rs 375.05 Cr. (Sanction date Nov. 1989)
- Capital Investment (till : Rs 1038.41 Crs (Including Rs 494.85 Crs 31.03.2012) replacement capital)
- Mining block area : 1110 Ha.
- Lease hold area : 2717 Ha.
- peak production capacity of 25 Mtpa

Over burden removal jayant project

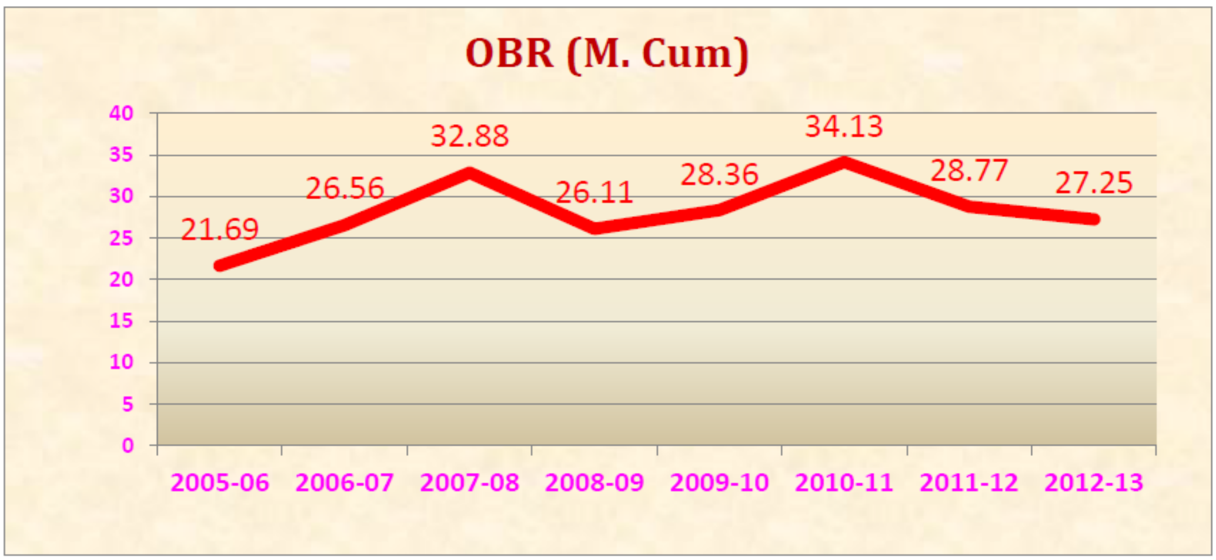
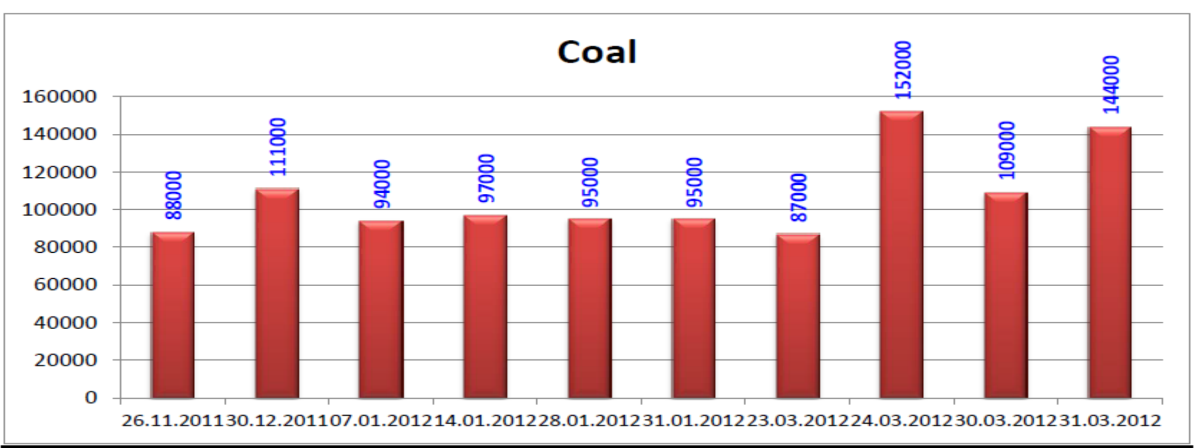


Fig: 2.2 Over burden removal jayant project

Jayant 20 MTPA expansion programme



Fig; 2.3 Jayant project coal production

2.5.2 Amlori project NCL Singrauli

The feasibility study prepared by CMPDI with participation of Russian experts in 1974 has identified Amlori open cast mine with rated capacity of 10 MT/year. The Amlori black stand as high plateau over the Talchair plains in the south. The plateau raises a maximum height of 520m above the MSL.

- Feasible report sanctioned on – 25/06/1982
- Capital investment – Rs. 323.32 crore
- Revised coal estimated sanctioned – Rs. 527.11 crore
- Coal production start – 1987-88
- Seam gradient – 2 - 5
- Stripping ratio – 4.41
- Depth of quarry – 300m
- Mineral reserve – 325.04MT
- Volume of overburden – 1434.38 M cum

2.6 COAL RESERVES IN INDIA

GSI estimated a total of 257.38 billion tonnes of coal reserves on 1.1.2007 of which are the "Prime" coking coal are 5.313 billion tonnes, semi-coking and medium coals are 27.04 billion tonnes and non-coking coals are 225.03 billion tonnes.

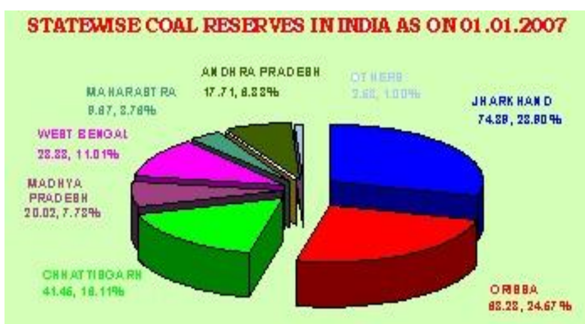


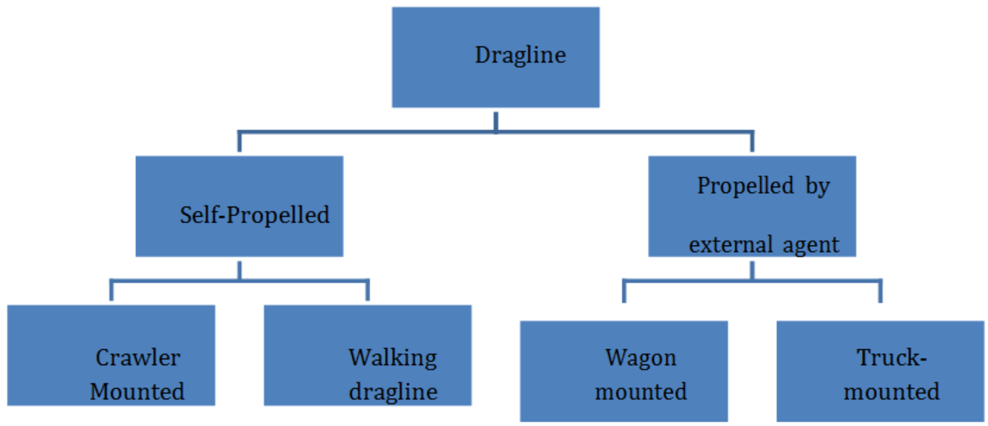
Fig: 2.4 COAL RESERVES IN INDIA

2.7 Presently major manufacturers Company of draglines.

- Bucyrus Erie (US)
- Page (US)
- Marion (US)
- Rapier and Ransom (UK)
- Soviets.

Chapter 3
Operation of Dragline

3.1 Classification of draglines



3.2 Selection of Mining Equipment depend on the following parameter

- Stripping Ratio
- Life of the mine
- Demand of coal
- Available of electrical power
- Available of manpower
- Amount of capital investment
- Type of land
- Geological parameter
- Infrastructure available
- Proposed annual output
- Technology available

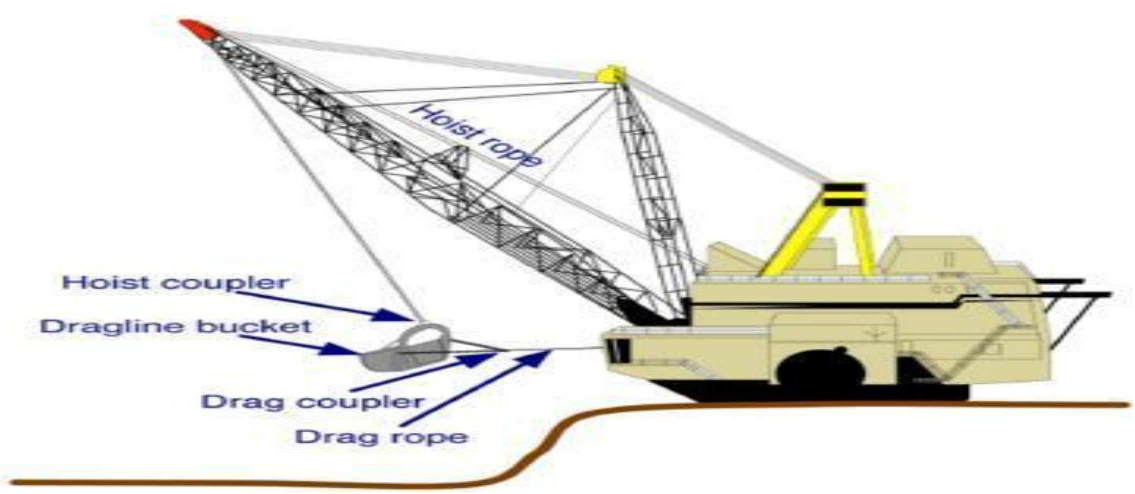
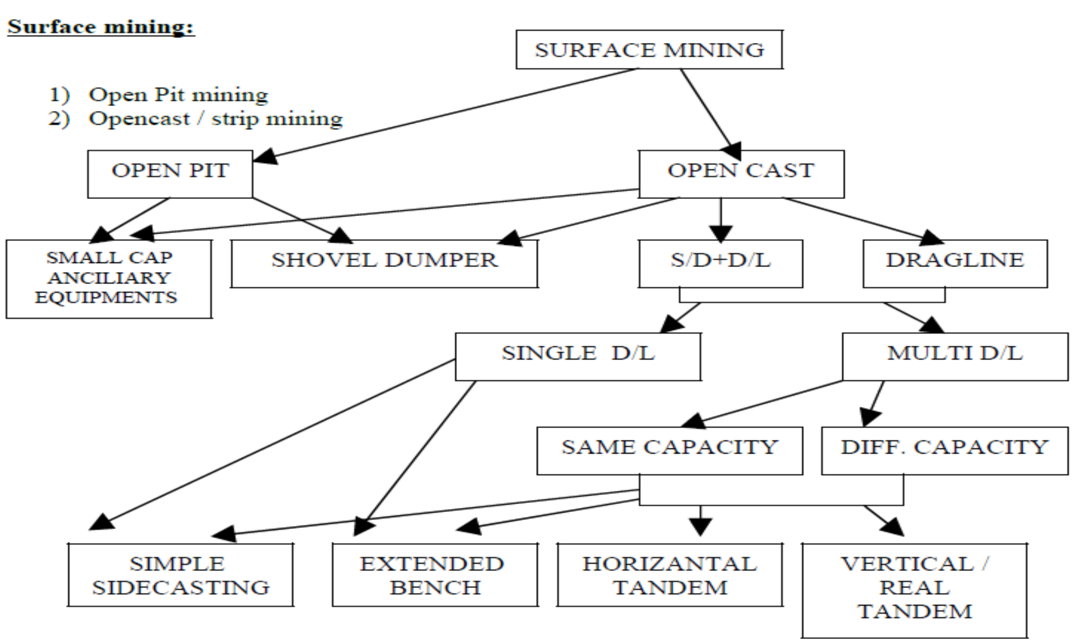


Fig. 3.1: Line diagram of dragline

3.3 Conditions suitable for dragline mining

1. Gradients flatter than 10˚ (1 in 6)
2. Seams should be free of faults, fracture & other geological disturbances.
3. Deposits with Major Strike length are available.
4. Thick seams with more than 25m thick are not suitable.
5. A hilly property is not suitable.
6. Property should have at least 15 years life.
7. The ' *King pin*' of the mine.
8. 40% of the OB is handled by the Draglines.
9. High Cost, for 24/96 Dragline is Rs. 160 Crore
10. Loss per hour Rs. 2,00,000/- approx., if not worked



3.4 Advantages of dragline mining

- Direct Disposal
- Can also be used to dig above working level at reduced production rate
- Less frequent movement
- Not significantly affected by the adverse weather
- Safe from unstable slopes, pit flooding etc
- Flexible, can be applied in different operating techniques

- Lowest cost per unit moves

3.5 Disadvantages of dragline mining

- Requires bench preparation; Max slope: 2%   Max ramp : 10 %
- Does not dig poor blast well
- High investment Cost
- Rehandling reduces the productivity
- Additional leveling Cost of spoil peaks

Fig: 3.2 Dragline Abhimanyu at NCL Amlohri

WALKING DRAGLINE

MODEL : WD 24/96

MAKE : HEC – RANSOM & RAPIER

WORKING DATA

BUCKET CAPACITY	24 CUB. METRE
BOOM LENGTH	95.6 METRE
BOOM ANGLE	30°
OPERATING RADIUS	88 METRE
MAX. DUMP HEIGHT	39 METRE
MAX. DIGGING DEPTH	53 METRE
AVERAGE GROUND PRESSURE	1.03KG/SQ.CM
CLEARANCE RADIUS	22 METRE
WIDTH OVER BOTH SHOES	23 METRE

BOOM HEADS HEIGHT	54 METRE
WEIGHT OF THE MACHINE	2000 TONNE
WALKING SPEED	240 MPH (35 SECONDS A STEP)
LEGNTH OF A STEP	2.3METRE
PRODUCTION CAPACITY	3.6 MILLION CUB. METRE PER ANNUM
DATE OF COMMISSIONING	1.10.1983
PROGRESSIVE WORKING HRS	1,77,632 HOURS
PROG. MATERIAL HANDLED	111 MILLION CUB. METRE
AVG. WORKING HOUR/DAY	18.5 HOURS

BUCKET

WEIGHT	32 TONNE
MAX. SUSPENDED LOAD	77 TONNE

AIR SYSTEM

MOTOR	15 KW
MAX. WORKING PRESSURE	14 BAR
FREE AIR DELIVERY	29.37 LITRE/SECOND

ELECTRICALS

POWER SUPPLY	6.6 KV, 50 HZ, 3 PHASE
HOIST MOTORS	1300 HP , 475 V
DRAG MOTORS	1300 HP, 475 V
SWING MOTORS	640 HP, 475 V
WALK MOTORS	640 HP, 475 V
MOTOR GENERATOR SET	2 x 1750 HP
EXCITERS	65 KW, 33 KW
AUXILLIARY TRANSFORMER	440V, 50 HZ, 3 PHASE

3.6 ANNUAL PRODUCTIVE CAPACITY

Production index, is defined as the bank measure of O/B volume moved per period per rated bucket volume. This measure is quite helpful in comparing productivity of different dragline of dragline make and capacities. The index can also be used in the machine selection procedure when used to calculate required bucket capacity per period given the O/B volume per period. "Production Rate" can be defined as the bank measure of O/B per period

Production Index: 2,50,000 m^3 / m^3 bucket /year

2.5 Yearwise % of total volume handling by draglines in NCL during '96-'06

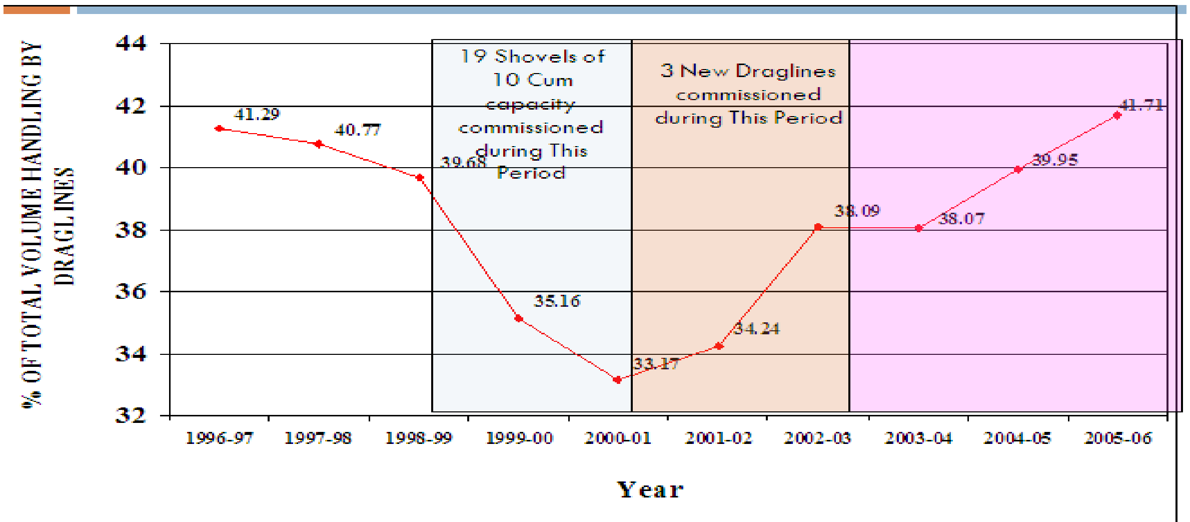


Fig: 3.3 Year wise % of total volume handling by dragline in NCL during "96-06"

3.7 Factors Affecting the Dragline Productivity

- Digging hour
- Cycle time
- Digging pattern
- Method of digging
- Method of excavation
- Blasting
- Dig position plans
- Operational delays(idle hours)
- Maintenance delays(down hours

3.8 Idle hours

- Shift change
- Field switch/cable shifting
- Face dozing
- Blasting
- Platform preparation
- Power failure

Table 3.1 Idle hour analysis

IDLE HOUR ANALYSIS

Total Idle hours	516	% of idle hours	% of shift hours
Field switch shifting/cable shifting	33	6.4	0.4
Face Dozing	218	42.2	2.5
Blasting	67	12.9	0.8
Power problem	182	35.3	2.1
Others	16	3.1	0.2

3.9 Cycle time

One cycle time consists of

1. Drag to fill
2. Hoist & swing to dump
3. Dump
4. Lower & return swing
5. Position bucket

Cycle time 24/96 dragline at rated parameters at 120^0 swing angle, 50 metre depth, 38 metre dump height

= 67.21 seconds

If the swing cycle time is reduced by *one second*, dragline productivity increases by 90,000 m^3 /year i.e. *2.5% increase in productivity*

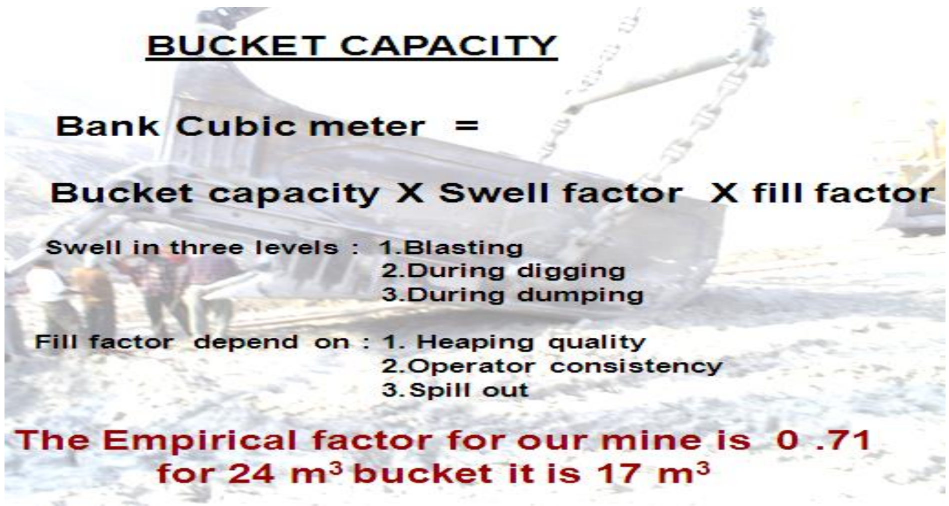
3.10 Factors Affecting Cycle Time

- Material characteristics
- Bank preparation
- Digging depth
- Hoisting height
- Swing angle
- Rope & swing speeds
- Operator's proficiency
- Equipment placement & scheduling

- Slope of digging face

3.11 To Reduce Cycle Time of dragline

- Sharp bucket teeth and shroud increases bucket fill factor, reduces bucket fill time
- A well balanced light weight bucket
- Good pick up and carry angle – reduces spillage
- Digging in systematic pattern
- A good carrying angle and hoisting under boom prevents tight lining, reduces bucket fill time by increase hoist speed



3.12 Maximizing payload is dependent upon the following:

- Geological condition mines
- Blasting (blasting pattern, types of explosive)
- Monitor weighing accuracy
- Engage location from the dragline
- Disengage Location
- Rigging mechanism
- Suspended load of bucket
- Bucket characteristics (cutting & penetration)
- Operator capability (operator skill)
- Minimizing rehandle of overburden

3.13 Dig rate

- Swing angle more than 120^{o} decrease by 15 %
- When cleaning the terrain to be excavated -decrease by 10%

- When damp to be excavated – decrease by 10%
- With oversize content – decreases by 10-15%
- With re-excavation –increase by 10%
- With top cutting – rocks decrease by 10-15%

3.14 Digging pattern

- Walk up on digging face
- 45^{o} digging face
- Systematic bucket spotting
- Reduce bucket fill length
- Pushing in the roll of materials
- Control bucket depth
- Follow the previous operator's pattern

3.15 Method of Digging

- Box cut
- Key cut
- Strip cut
- Chop down cut
- Ramp cut

3.16 Chop down cut

- produces only 75 % of conventional cut
- low bucket fill factor
- increased drag time to fill
- increased dozer work
- increased down time
- increased repair cost

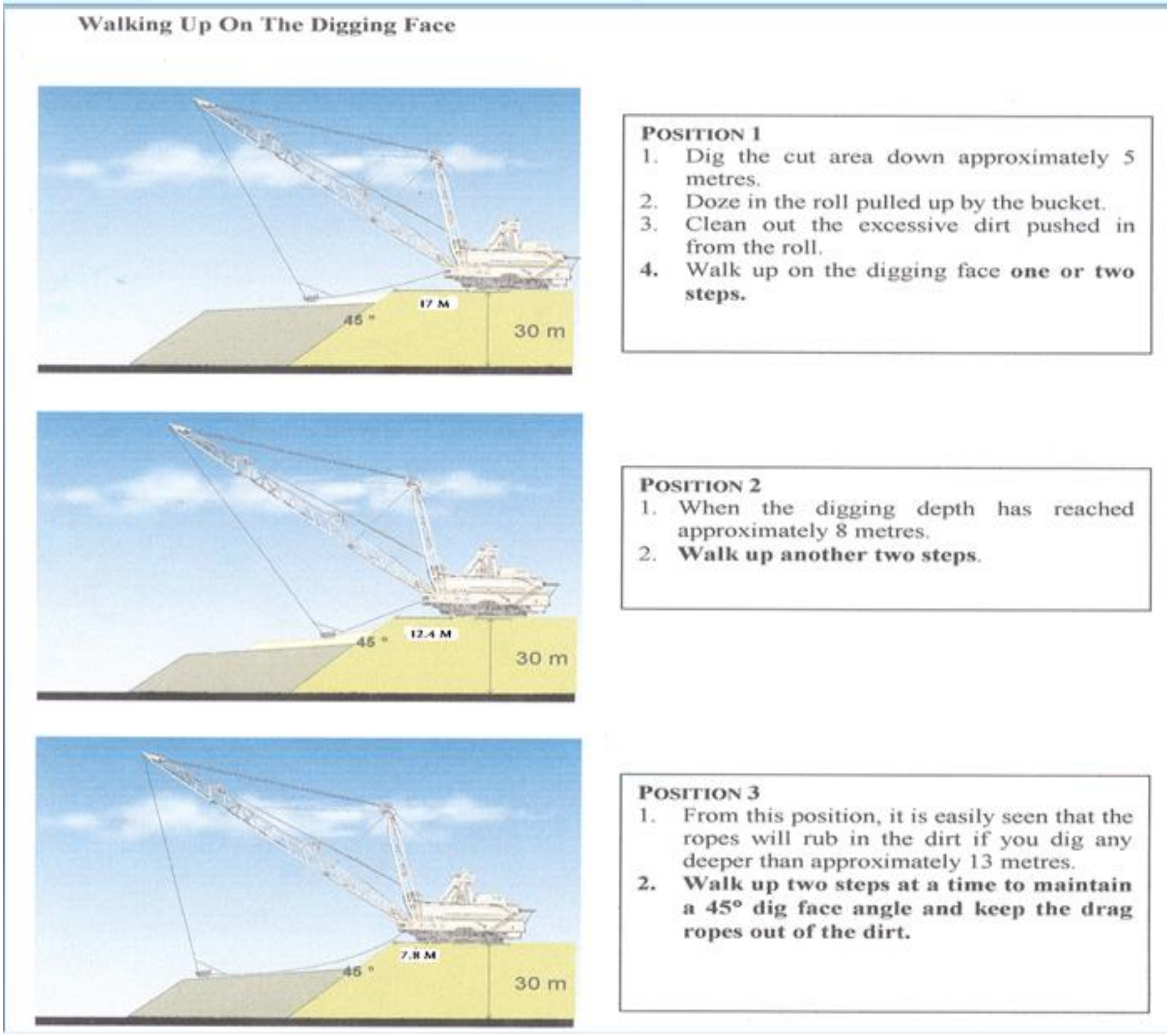


Fig: 3.4 different postion of digging face

3.17 Condition Monitoring

To determine its current state of health in order to prevent & prevent impending failures systematically, arise from human observation, checks & laboratory tests, from instruments etc

CM Levels

- Visual
- Assistance Monitoring - Using instruments
- Lubrication Monitoring, physio chemical testing, Wear debris analysis
- Monitoring with alarm

CM Methods

- Visual
- Potential Failure effects Monitoring
- Performance Monitoring
- Fore casting

Rubbing effects:

Particle effects: Lubricant Analysis
Wear debris analysis

Chemical effects: Element Monitoring

Dynamic effects:

Shock pulse monitoring
Vibration Analysis
Noise Monitoring

Physical effects:

NDT
Temperature effects: Thermography

Electrical effects:

- Condition Monitoring is done every 6 months by Separate a Cell at Jayant
- Detailed report system wise is submitted to the all levels

3.18 Analysis Methods

They are categorized into 4 areas, as outlined

Motion analysis

- Characteristics of Electrical motor - Current/ Voltage (Torque/ Speed) curves.
- Short term measurements / High speed :- Motion rates (Drag, hoist, and swing operation individually) with a step change in operator reference from full stop position

Cycle analysis

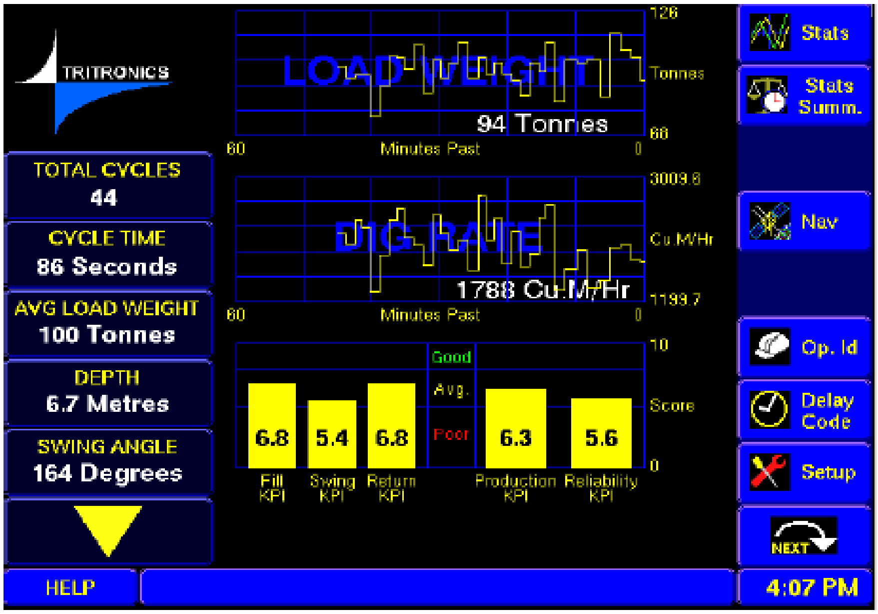
- Dragline Cycle times, such as fill time, swing time, dump time, return time.
- Hoist dependent swings operation of dragline.
- Payload weight of bucket.

Production demographics analysis

- Production rate per dig hour of dragline
- Total target vs. production.

Qualitative analysis of dragline

- interview / Survey operator



Fig; 3.5 demographics analysis

3.19 Dragline operation in tandem-vertical and tandem horizontal mode

Vertical tandem mode having the following conditions:

1. Thickness of over burden that are removed by dragline is more than the digging depth.

2. When used in vertical tandem mode Bench height keep limited by drilling depth

3. When increased rate of coal exposure of open cast mine, it is necessary to required thickness of bench always less than of dragline.

Table 3.2 Machine parameters and Key field parameters that are used to make balancing diagram of vertical tandem mode of operation

Sl. No.	Parameters	Details
1	Draglines	
	D/L-1(LeDL-VT)	15/90 with max. horizontal reach of 82 m (top portion)
	D/L-2(LaDL-VT)	24/96 with max. horizontal reach of 88 m (bottom portion)
2	Bench height	Approx. 42 m (14 m as top portion and 28 m as bottom portion)
3	Cut width	85 m
4	Strip length	2,000 m
5	Highwall slope	70°
6	Bench slope	60°
7	Key cut width at top	38 m
8	Key cut width at bottom	5 m
9	Coal rib	Left for full height (triangular section)
10	Angle of repose	38°

Advantages Horizontal tandem mode operation of dragline as compared to vertical tandem mode of operation of dragline

1. In horizontal tandem mode of operation increased width of the dragline cut due to this reduce idle time for marching and power shut down of dragline.

2. Better supervision of concentrated area of operation of both draglines due to this is possible in this mode of operation of dragline.

3. In this mode of operation increase over burden bench thickness of overburden, dumping height of overburden material for the lagging dragline, which is exposing coal easily, poses no any problem.

4. Less swing angle and less problem of dumping height this increase the productivity.

Table 3.3Horizontal tandem mode, Weighted and overall cycle time for 24/96 lagging dragline Abhimanyu (LaHT-D/L) and rehandled muck (loose over burden) for mine.

Sl. No.	Mode of operation	Swing angle (°)	Observed cycle time for 24/96 (LaHT-D/L) for blasted muck (s)	Observed cycle time for 24/96 (LaHTD/L) for re-handled muck (s)	Weighted cycle time for blasted muck (s)	Weighted cycle time for re-handled muck (s)	Overall cycle time (COA) for 24/96 (LaHT-D/L) (s)
1	HT	Up to 90	74.96	65.11	81.16	71.25	**77.20**
2	HT	>90–120	81.68	73.93			
3	HT	>120–150	89.45	78.57			
4	HT	>150–180	98.40	84.29			

Table 3.4 Machine parameters and Key field parameters that are used to make balancing diagram of horizontal tandem mode of operation.

Sl. No.	Parameters	Details
1	Draglines	
	D/L-1(LeDL-HT)	24/96 with max. horizontal reach of 88 m
	D/L-2(LaDL-HT)	24/96 with max. horizontal reach of 88 m
2	Bench height	Approx. 35 m
3	Cut width	90 m
4	Strip length	1,700 m
5	Highwall slope	70°
6	Bench slope	60°
7	Key cut width (at top)	38 m
8	Key cut width (at bottom)	5 m
9	Coal rib	Left for full seam height (triangular section)
10	Angle of repose	38°

3.20 Method of Excavation

- simple side casting
- advance bench excavation
- extension bench excavation
- pull back excavation
- box cut excavation
- tandem excavation

In the field study, it can be concluded that single dragline operation without rehandling is the preferable method if the production requirement can be satisfied. However if large production desired and extended bench method with single dragline adopted than tandem operation of dragline may be seriously considered. However this will entail capital expenditure on the purchase of a second dragline but the substantial savings which will result in terms of cost per tones of coal exposed will ultimately result in better economy for the mine.

Chapter 04

Drive Technology of a Dragline in Open Cast Mines

4.1 Variable Speed drives in dragline

Variable speed drive used in dragline operation for increasing the efficiency and life time of the dragline, different type of drive system used such as SCR based, IGBT based etc. Variable speed drives (VSDs) with PLC controller are used to smoothly start large motors and continuously adjust the speed according to loading condition of machine. DC motor, Induction and synchronous motors driving conveyors, excavators use VSDs to provide high power, good controlling, adjustable speed control, as well as regenerative breaking used to regenerate significant amount of energy. Mechanical system used such as throttling valves, gears, or turbines, to control speed and flow this can be replace by electric drives. Electric drive having no moving parts, they provide very high reliability.

4.2 Advantage of variable drive system

1. Increased Reliability of the system
2. Good Control over dragline
3. Significantly Less Maintenance
4. Soft Starting of motor , generator or M-G set and Improved Power Factor
5. Cost savings of control system
6. Smooth motor starting.

4.3 Methods of speed control

The speed of the motor change with respect to driven load and according to the operating performing. Electric motors and generator (M-G set) coupling combinations used for altering the speed control "*Speed Source*" or a "*Torque Source*". Two types of control used in motor.

- When driven load is driven at a constant speed independent of load torque is called "Speed Source" controller.
- Where the driven load is driven by a constant torque and the speed alters to the point where the torque of the driven load equals the torque delivered by the motor is called "Torque Source" controller.

When used in closed loop controllers employ a feedback loop to convert a "Torque Source" into a "Speed Source" controller.

4.4 Ruggedized DC-EXX Modules

The Ward Leonard system used in dragline to control the speed of M-G set. In this system of DC motor speed control done by two basic means of control system.

1. **Generator output voltage (*a u*) control system**

In this mode of operation, the drive motor current *fm i* is kept constant and generator field current *fg i* value is changed so that output voltage (*a u*) varies. Hence speed rises to the base speed. In this mode of operation torque can be maintained constant during operation.

2. Drive motor field current (*fm i*) control system

When weakening the field current of the drive motor, the speed of motor rises greater that the base speed. In this mode of operation time output (*a u)* is kept constant and the drive motor (*fm i)* field current is decreased and motor speed increase. Hence Armature current is constant. Torque decreases as speed increases because torque inversely proportion to speed .

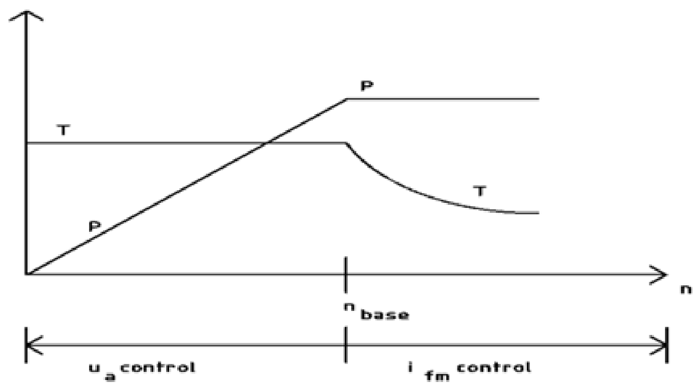
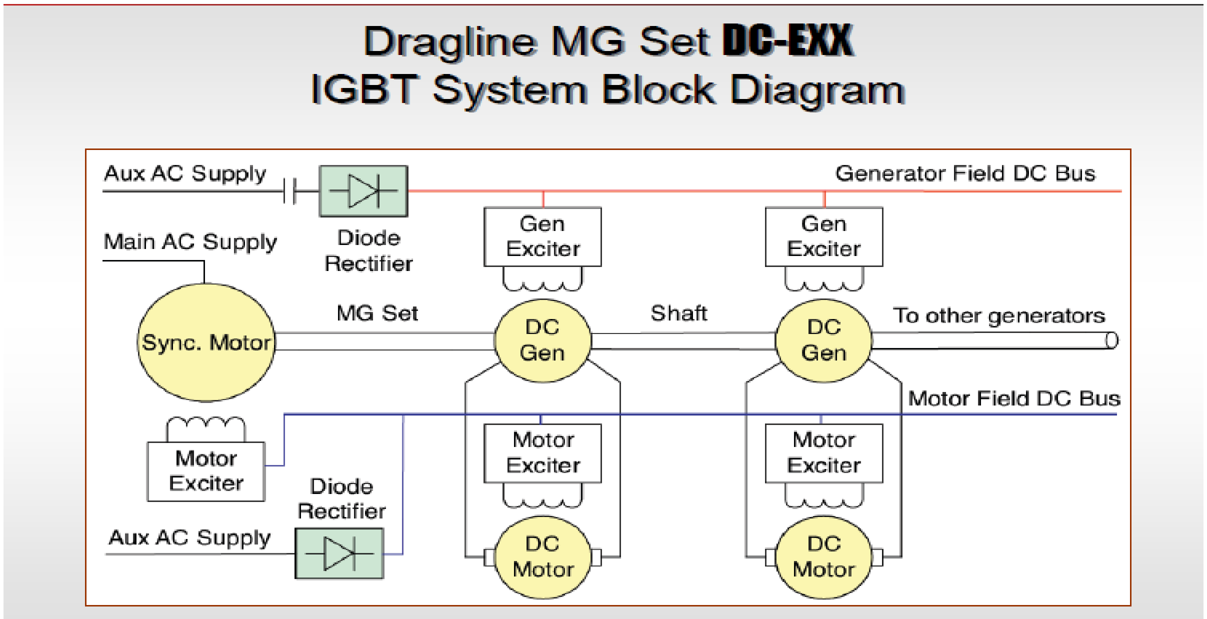


Fig: 4.2 Drive motor field current

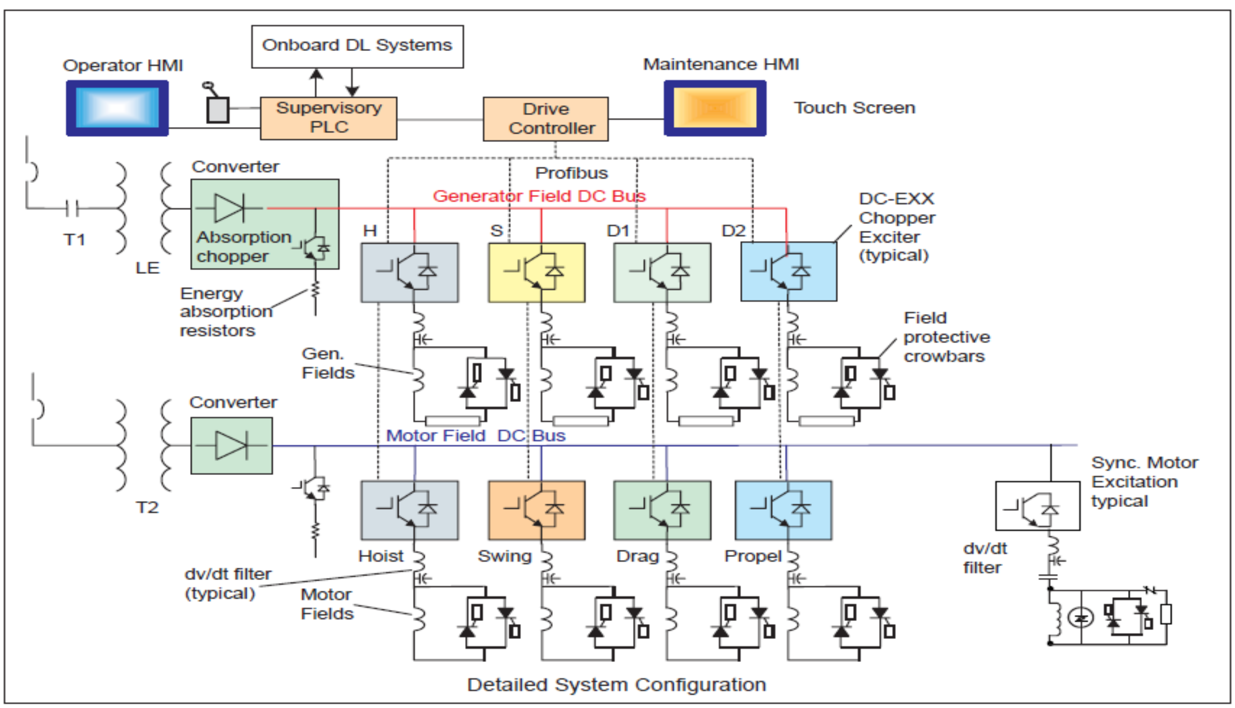
In this mode of control system in dragline adjustments can be done at the same time or separately. When altering the excitation power of the generator resultant in speed changes from zero speed to base speed. In this type of arrangement usually prime movers run on a constant speed, when lowering the excitation current of the DC motor raise the DC motor speed of the motor.

4.5 DC Converter

- 220-440 V 3-phase ac input supply used by using auxiliary transformer.
- 300-600 V dc output by using reactifer.
- 350 or 750 Amp output current capacity of the system.



Fig; 4.3 Dragline M-G set



Fig; 4.4 Different mode of control of dragline drive system

4.6 Regenerative Braking of dc motor

Mechanical breaking systems convert kinetic energy into heat, usually break shoe by friction. Regenerative braking use their drive motors to convert kinetic energy into electromagnetic energy. Motors and generators operate under the same principle and can be used interchangeably**. Regenerative braking** is done when the generated energy in breaking time is supplied to the source. Necessary condition of regenerative breaking shows in this this equation:

E > V and negative I_a.

$$\omega_m = \frac{V}{K_e\phi} + \frac{R_a}{(K_e\phi)^2}T$$

And back EMF, E= NP ΦZ/60A

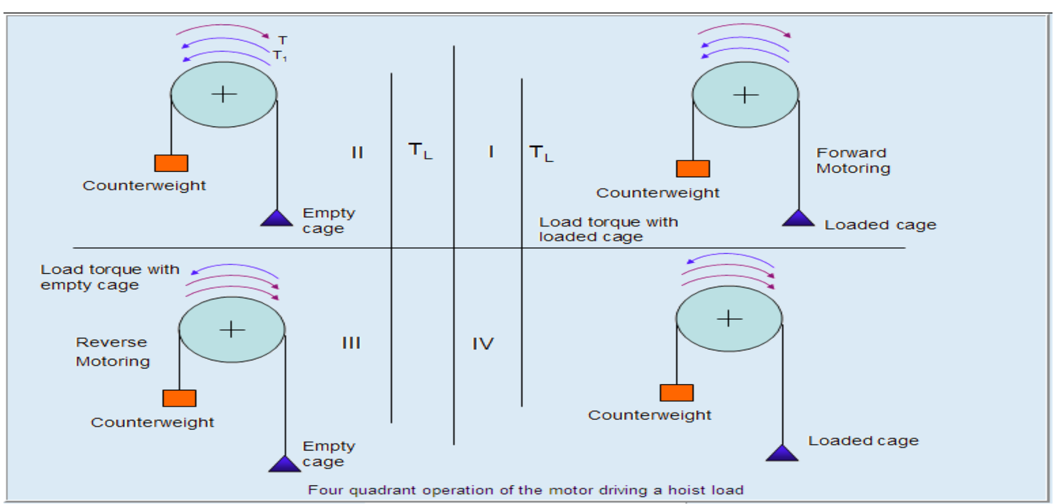
Where, Φ flux, P no. of pole, N speed in rpm, Z no. of conductor, A no. of parallel pat, **Speed of a motor** can be controlled by.

- Voltage of Armature control.
- Field flux control of DC motor.
- Armature resistance control by using external rheostat.

The field flux of motor can't be increased beyond a rated value (base value) so the regenerative braking of DC motor is possible only when the speed of motor is higher than the rated value of speed.

4.7 Four Quadrant Operation Chopper Drive

A chopper is a static device that converts fixed dc input voltage to a variable dc output directly.



Fig; 4.5 four quadrant operation of motor

1. In the first quadrant the load torque acts in the opposite direction to that of rotation. Hence

to drive the loaded hoist up, the motor developed torque must be in the direction of the rotation or must be positive. The power will also be positive so, this quadrant is known as **'forward motoring mode'.** In the first quadrant the load torque acts in the opposite direction to that of rotation.

2. The hoisting up of the unloaded cage is represented in the second quadrant. As the counterweight is heavier than the empty cage, the speed at which hoist moves upwards may reach a very high value. To avoid this, the motor torque must act in the opposite direction of rotation or motor torque must be negative. The power will be negative though the speed is positive, so this quadrant is known as **'forward braking mode'**.

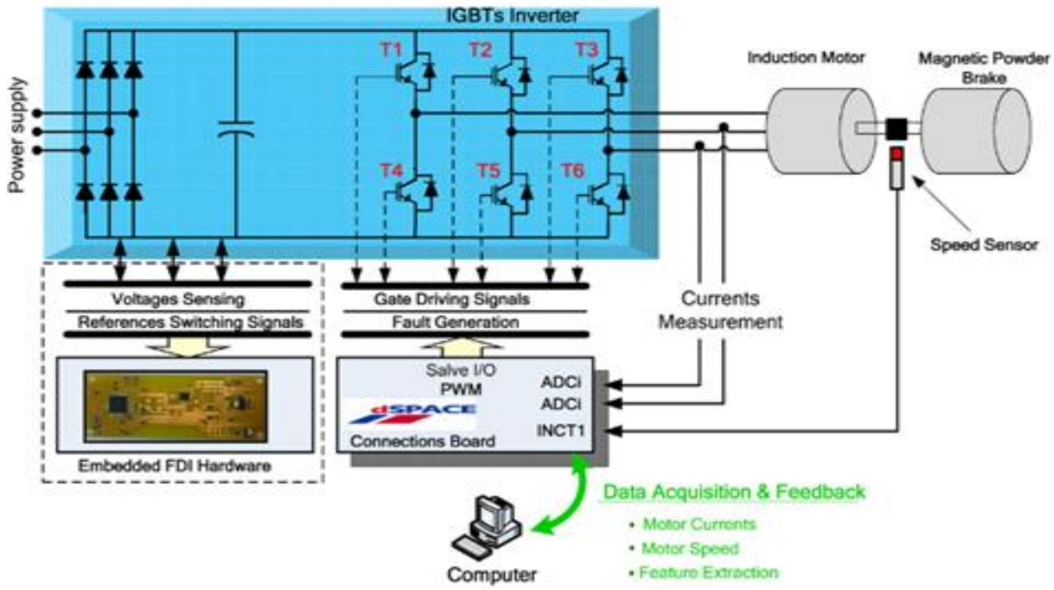
3. The third quadrant represents the downward motion of the empty cage. Downward journey will be opposed by torque due to counterweight and friction at the transmitting parts, move cage downwards the motor torque in the direction of the rotation. Electric machine acts as a motor but in the reverse direction compared to first quadrant. The torque is negative as speed is increased in the negative direction, but the power is positive, this quadrant is known as **'Reverse motoring mode'**.

4. Fourth quadrant has the downward motion of the loaded cage. As loaded cage has more weight than the balanced weight to limit the speed of the motion, motor torque must have opposite polarity with respect to rotation and acts as a brake. The motor torque sign is positive, but as speed has negative direction; the power will be negative, this quadrant is designated as **'Reverse braking mode'**

4.8 AC Technology

The main components of an AC drive are used to able the required level of current and voltage. The controls have to be able to provide the user with necessary adjustments such as minimum and max limit of speed settings, so that the drive can be adapted to the user's process and aureate control.

AC drives can be classified as current-controlled AC drives and voltage-controlled AC drives. Vector control and direct torque control belong to the current- controlled AC drives while V/f control and the proposed AC WLDS belong to the voltage-controlled AC drives. Similarly to AC dives, the inverters in smart grid integration can be current-controlled or voltage-controlled



Fig; 4.6 Experimental setup drives

4.9 AC Main Motion Drive Motors

- In dragline, AC squirrel-cage inductions motors power swing, drag, hoist, and propel motions are used.
- Built in speed sensor are used so that it's replaceable without removal of motor from service can be easily done.

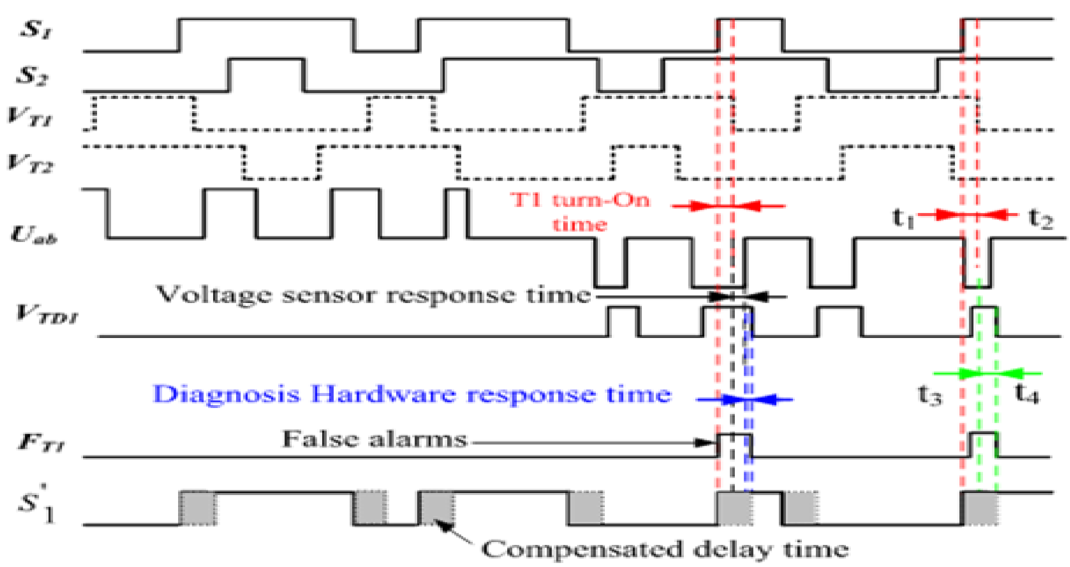


Fig 4.7 Diagnosis system of dragline, IGBTs-switching, voltage sensor and delay times compensation on the fault detection signal in different condition

4.10 Barriers to AC

- Evolutionary upgrades with analog and digital control of drive system in dragline
- AC drive provide reliable operation but limited
    - ➢ Efficiency of ac drive system
    - ➢ Productivity increase
    - ➢ Low Maintenance required
    - ➢ Operating costs reduce
- Strict utilities requirements on allowable voltage fluctuation, power factor at the PCC and levels of harmonic injection
- This can be overcome with Active Front Ends (AFEs) in place of normal rectifiers. This makes static AC drives a superior alternative to M-G set drives.

4.11 AC Gearless Dragline

Introduction – Configuration

- Replace multiple Hoist / Drag gears and DC motors with single synchronous gearless motor connected directly to the drum
- All M-G sets and gears for Hoist and Drag are eliminated
- Use geared static AC drives for Swing and Propel
- All M-G sets for the Swing are eliminated

20 % Higher Efficiency for AC Gearless,
20 % Lower Energy Cost

Existing Geared DC Drives	
Input Transformer	0.98
MG Set Motor	0.93
DC Generator	0.92
DC Motor	0.92
Existing Gearing	0.96
TOTAL Efficiency	**0.74**

AC Gearless Drive	
Input Transformer	0.98
AFE / Inverter	0.98
AC Integral Motor	0.93
TOTAL Efficiency	**0.89**

4.12 AC Conventional Dragline

Introduction - Configuration

- Replace multiple Hoist / Drag DC motors with AC induction motors.
- Replace multiple Swing / Propel DC motors with AC induction motors
- All M-G sets are eliminated

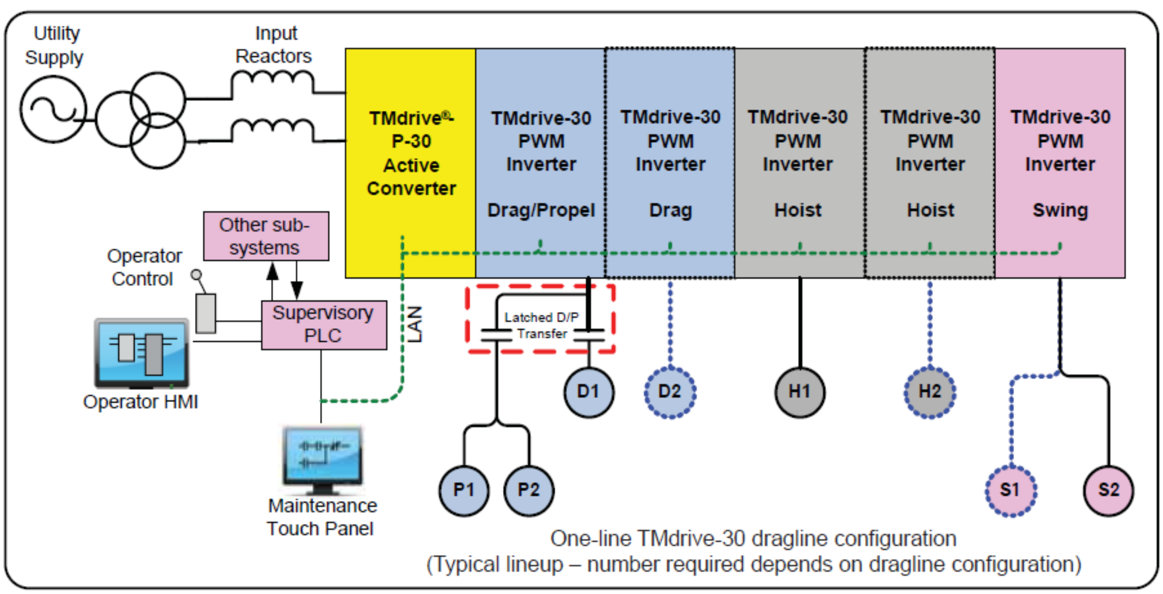
4.13 Advantage of AC convention drive

1. A key performance requirement of each of these configurations is that the machine must be able to obtain 0.80 leading power factor at the high voltage slip rings on the machine at the machines nominated peak power level. It is important to verify that the AC drive will be capable of sustaining a minimum VAR capability to achieve 0.80 leading power factors at the 22 kV incomer terminals of the machine on a consistent repeatable basis for the duration of the machine life with a **modulation index of less than 1.00**.

2. A: Modulation Index is defined as:

$$\frac{\sqrt{6}}{\pi} \times V_{DC} = m \times V_{AFE}$$

3. The drive systems can provide up to 0.8 leading pf at peak load at slip rings
4. Auxiliary load is typically 3.0 MVA with 0.8 lag pf
5. The peak load of the drives is 24.5 MW
6. 7/7/8 uses 30 AFEs with a modulation index of 0.89 to achieve 0.8 leading power factor.



Fig; *4.8 Drive control system of AC Conventional drive*

Thanks to quick and accurate drive control with reliable feedback it was possible to realize a very stable and smoothly operating machine without current peaks, which had been one of the main problems with previous DC system.

Benefits

- Higher reliability and lower maintenance costs
- Lower losses in drive system, saving 1,2 MWh/year
- Lower dynamic load – longer lifetime for gearbox and ropes
- 1–3 seconds shorter working cycle – 2–4% higher productivity
- 15 years longer lifetime for total dragline

After renovation, the dragline has an excellent dynamic performance and overload characteristics with the speed and torque control. There is less mechanical stress and guaranteed longer lifetime for the gearboxes. Its average productivity exceeds others by 10–40%. Also important is its energy consumption, which is 40% less than average.

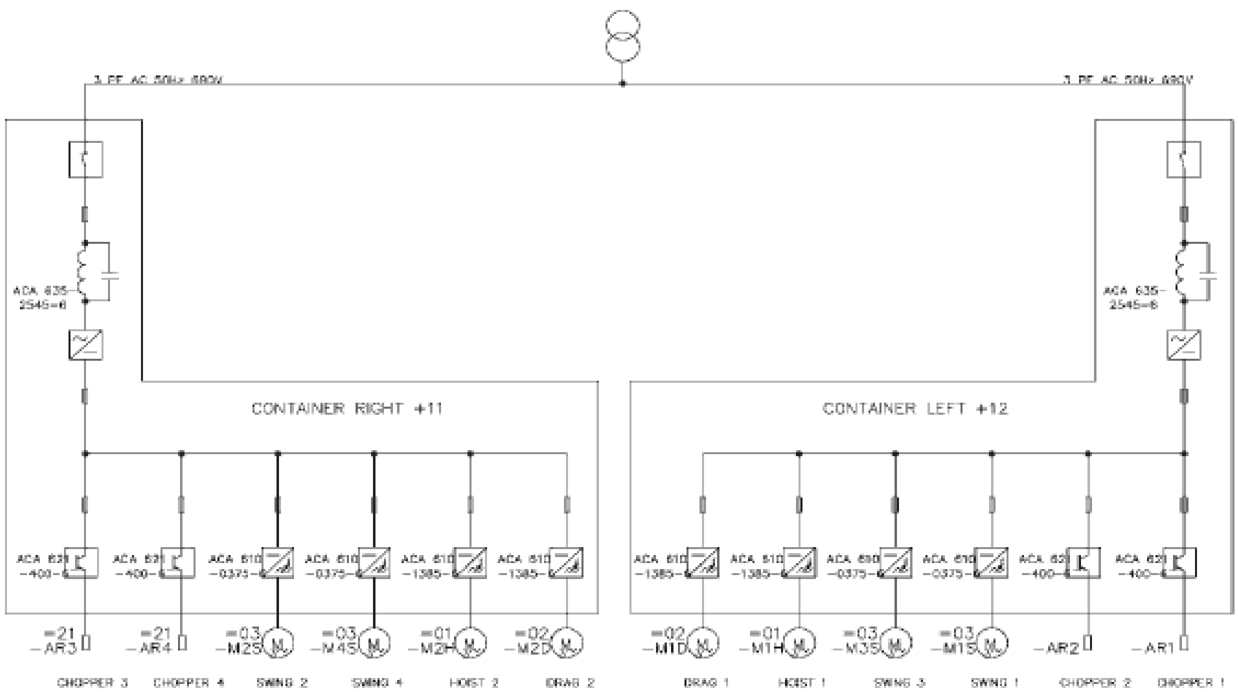


Fig.: 4.9 Principle connection of AC drive system

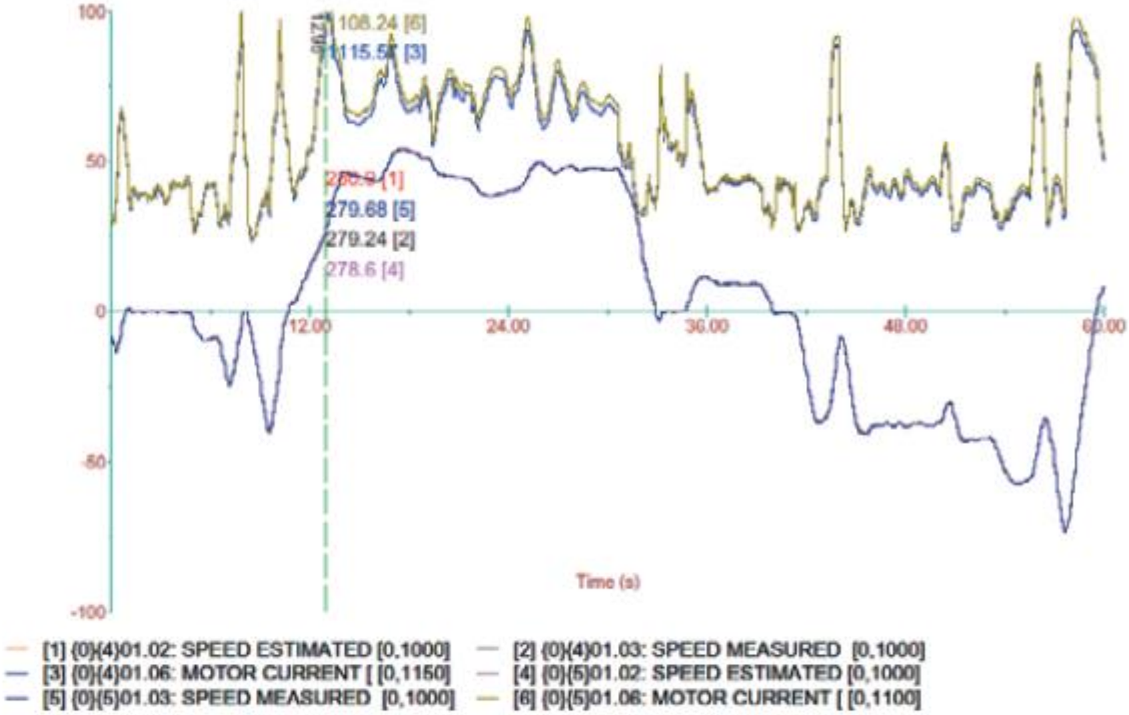


Fig: 4.10 Smooth operation with new AC drives

4.14 Availability / Reliability (compared to DC Ward-Leonard)

- Almost nil maintenance hours required on motors.
- No carbon brush replacement required.
- Less moving components *(by half).*
- No commutation wears.
- Less potential for unplanned failures *(i.e. motor flashovers).*
- No motor rebuild requirement *(50,000 hrs).*
- Less human interference & reliance on maintenance.

High Availability + Longer MTBF = Better Reliability

4.15 Drive Power Transformer (DPT)

Impedance Choice

- The impedance must be high enough for the AFE requirements
- The impedance must be high enough to limit the current rise in case of a short circuit and give the switchgear enough time to open
- The impedance must be low enough to allow sufficient regenerative VAr flow back to the

line

Impedance Level

- A gap greater than 50mm is inserted between the primary and secondary windings and this results in a loosely coupled system
- Not all the flux from the secondary winding links the primary windings.
- Most of the secondary flux closes through the gap between the primary and secondary. Hence the high impedance is concentrated on the secondary.
- This secondary leakage flux is proportional to the impedance of the transformer and creates an inductive voltage drop under load
-

4.16 AC IGBT/AFE Conventional

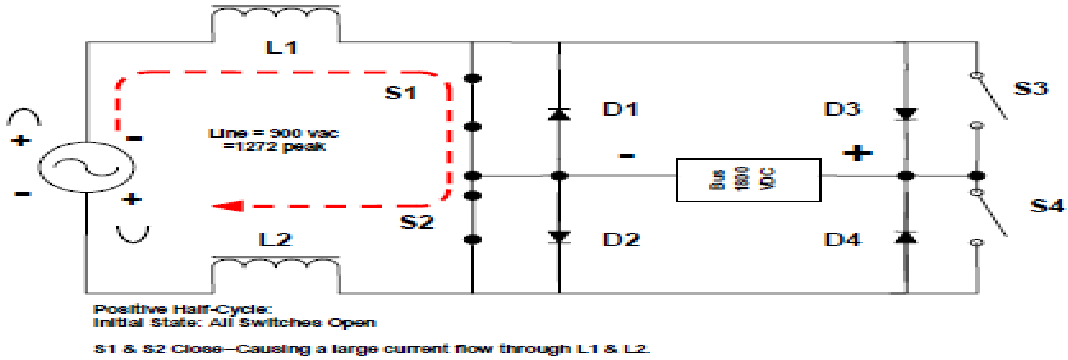
Why Conventional?

- Active Front End (AFE) using AC IGBT devices. *(Proven capability - Power factor capable of 0.8 leading).*
- AC motors plug directly into existing style gear cases. (*One-style motor required, common to all motions*).
- Performance / Productivity increases.
- Rugged Skid design for excavator use. *(Proven reliability).*
- Siemens SiBAS drive control. *(Proven reliability).*
- AC IGBT devices. *(Proven reliability)*.
- Water-cooled technology. *(Proven technology in transportation).*
- No carbon brushes. *(Reduced maintenance costs).*
- Complete remote diagnostic system *(Full system capability)*.

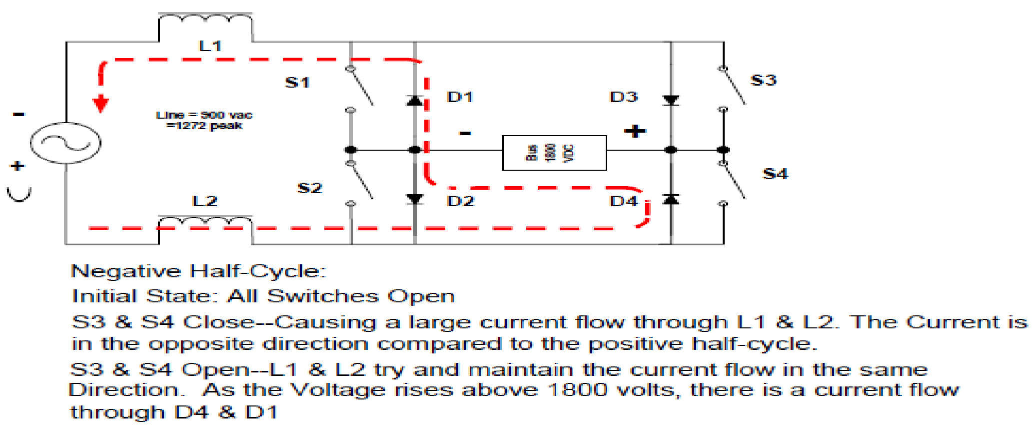
4.17 Active Front End (features)

Reliable operation of active front end rectifier but limited with respect to maintenance, efficiency, operating costs and productivity of dragline.

- It's providing leading Power Factor this makes Static Dragline Drives feasible.
- Chopper control system in four quadrant operations is used. Hence Regenerative feedback into the line supply easily.
- Low harmonics are fed back into the supply because sinusoidal line currents.
- When power fails in regenerative operation no commutation faults in this time.
- Voltage fluctuations of Line supply is less as compensated.
- Dynamic performance is extremely high.
- Power factor up to 0.8 leading.



Fig; 4.11 Positive half cycle of operation



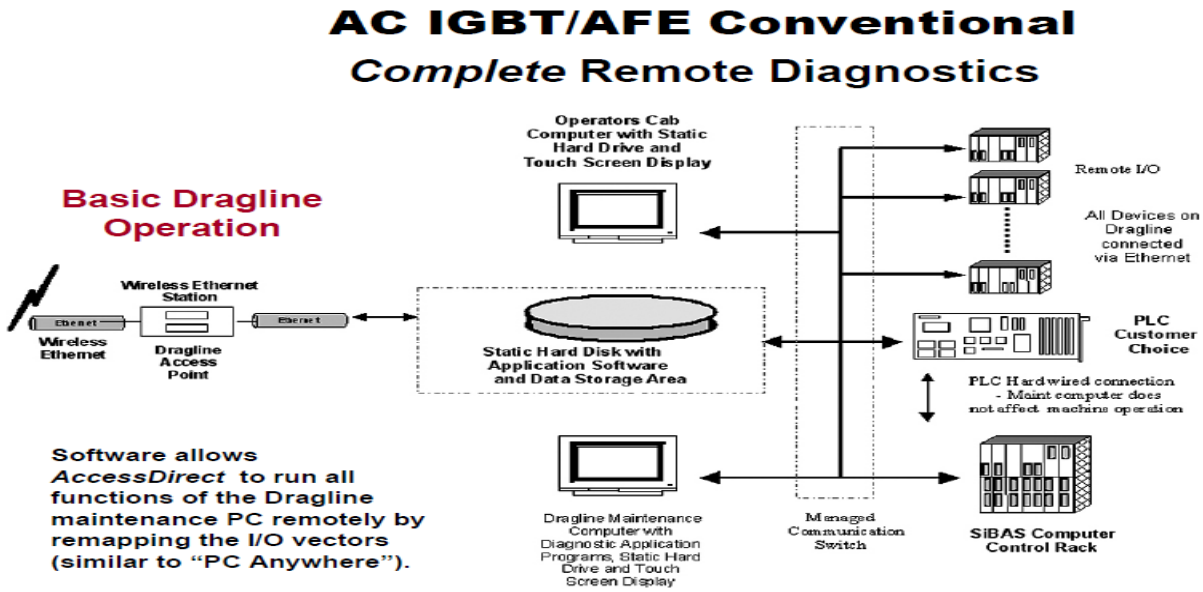
Fig; 4.12 Negative half cycle mode of operation

4.18 IGBT *(Insulated Gate Bipolar Transistor)*

IGBT used as power switches. Transistor needs only low power gating signal to turn on and off. IGBT power modules for Active Front End *(AFE),* inverter with "plug-in" design. IGBT's utilize simple, reliable, gate drivers without snubbers circuit and di/dt reactors IGBT can safely turn-off overload currents without damage (GTO's fail if overloaded even momentarily)

- High switching frequency of IGBT
- Means smoother current less harmonics and ripple
- Water cooled or air, no heat sink required.
- Cooled and NO Fuses

IGBT: 3300 V, 1200 amp
Motor voltage: 1400 V



Fig; *4.13 AC IGBT/AFE Convention drive*

Exciter System Drive Controller Role

• Drive Controller & Software is included in system for mode selections, tapered current limits, loop unbalance, etc.

• Excavator supervisory PLC [OEM or supplied as part of upgrade]

- Sends references, start-stop and hard contact control signals to drives
- Receives feedbacks over Profibus
- Has access to global data buffer for off board monitoring or onboard reporting

Chapter 05

Programmable Logic Controller (PLC)

5.1 PLC (Programmable Logic Controller)

Programmable Logic Controllers (PLC) to emulate conventional mechanical relaying schemes, protection, annunciation functions, for used DCS system. Modern PLCs can perform many Math and Logic Functions without additional Ladder Logic Programming

- Differentiation, Integration
- +, -, *, /
- Boolean Logic Functions (AND, NOT, OR)
- Master Control Functions (Reset, etc)

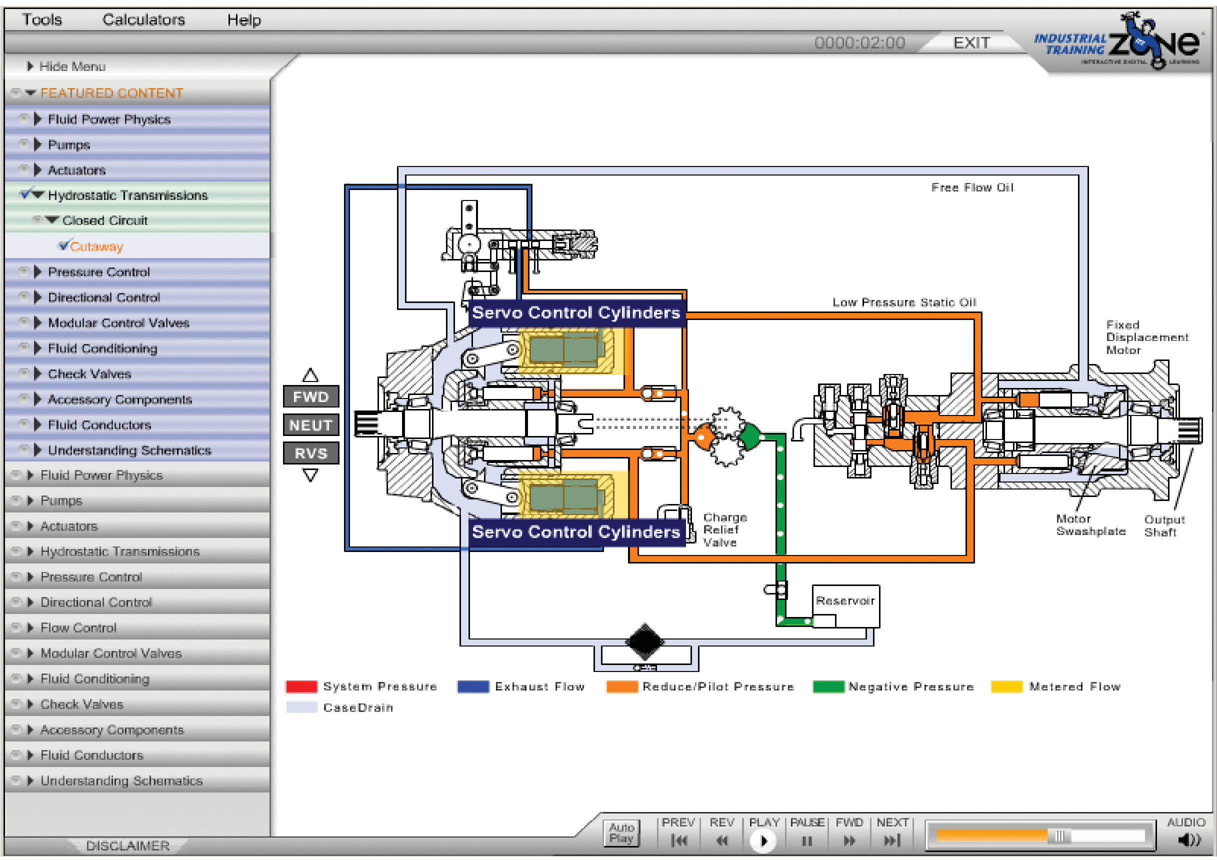


Fig: 5.1 PLC based Dragline Control

All drives and other devices are controlled by a PLC based system. The digital control system has been fully integrated with an extensive machine diagnostics package and touch-screen controls to speed maintenance work, increase operation efficiency and reduce down-time.

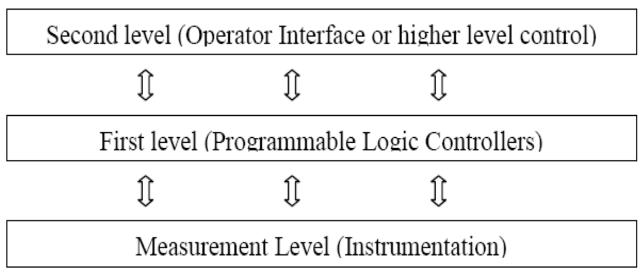
Essential Part of Motor Control Protect against:

➢ Under Voltage

- Over Voltage
- Maintain Frequency range (AC Machines Only)
- Over Current
- Over Heating
- Over Speed
- Over Load

5.2 PLC system of Dragline Lube Control

Lube System Control timers and Conventional relays can be replaced with PLC systems in dragline which provide improved reliability/repeatability and monitoring of signal along with ease of system with different stage of modifications.



5.3 PLC Scan

The PLC program is executing the input form CPU and performs communication and internal diagnostics and finally updates the status of outputs. This process repetitive referred to as a **scan**.

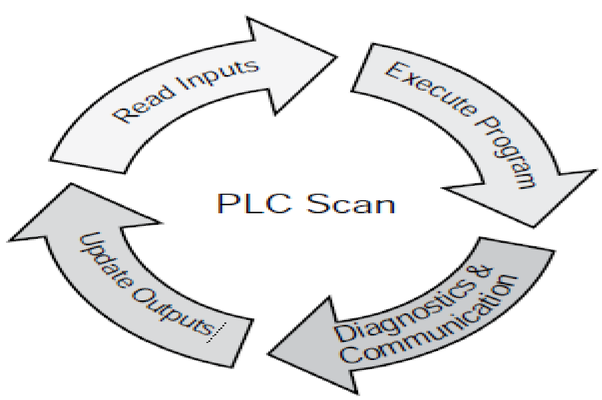


Fig: 5.2 PLC Scan

5.4 Memory used in PLC system having 3 types

1. **Read Only Memory (ROM)** is types of memory used were it is necessary to protect data or programs from accidental erasure.

2. **Random Access Memory (RAM)** RAM is used as a temporary storage area. RAM is memory that allows data to be written to and read from any address (location). RAM is volatile, meaning that the data stored in RAM will be lost if power is lost

3. **Erasable Programmable Read Only Memory (EPROM)** provides a level of security against unauthorized or unwanted changes in a program. EPROMs are designed so that data stored in them can be read, but not easily altered. Changing EPROM data requires a special effort. UVEPROMs (ultraviolet erasable programmable read only memory) can only be erased with an ultraviolet light. EEPROM (electrically erasable programmable read only memory), can only be erased electrically.

5.5 Basic Components of PLC:-

- Actuators
- Discrete Inputs and Outputs
- Central processor unit (CPU)
- Ladder Logic Programming
- Power Supply System
- Input / Output Module System
- Programming Device
- Time

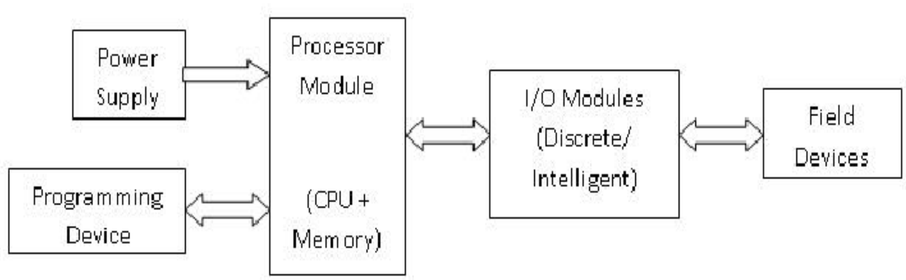


Fig: 5.3 General view of PLC system

5.6 Basic Operation of PLC system in dragline:-

The basic operation of PLC is given by 3 steps.

1. Read the input from field status used devices such as sensor, transducer
2. Solving or Execution the logic from input,
3. **Updating the output status shown on the screen of diagnostic system**

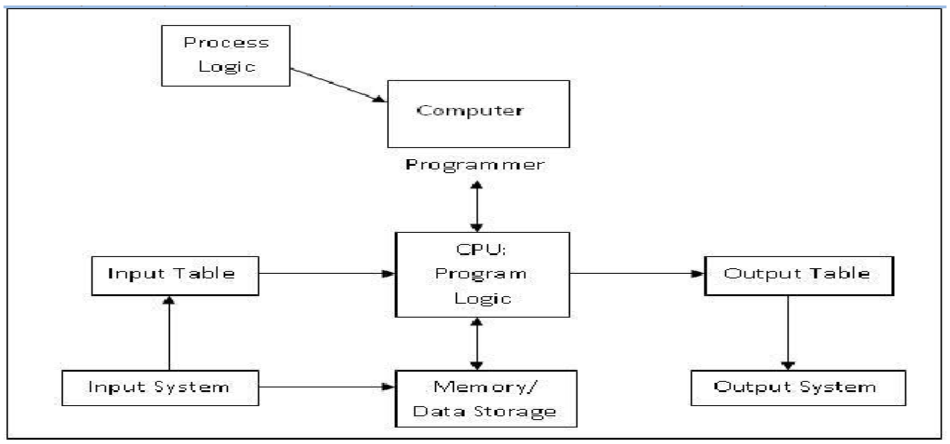


Fig: 5.4 Operation of a PLC System

5.7 PLC Input and Output Devices of dragline:-

Two type of system used in input output device

1. Digital - binary system used in input / output devices which must be in one of the two states: on or off. Digital system such as relay, solenoid valves, motor starter etc.
2. Analog - continues devices - sense and respond to set the range of values in input / output device. Analog system such as valve position, air pressure, motor speed etc.

5.8 PLC Special Features

- Time Delay Relays
- Counter Relays
- Special Functions
- User Defined Functions
- Special Bits

5.9 Time Delay Relays

- When TD Relay Pick-Up Coil is Energized, a Delay is Initiated
- Normally Open Contacts Wait to Close until Delay is Completed
- Normally Closed Contacts Wait to Open until Delay is Completed
- Very Useful for Creating a Sequence of Control Events

5.10 Counters

- Counter Relays must "Count" a pre-determined number of events before changing contact status
- Can Count Up (Up Counter) or Count Down (Down Counter)
- e.g. An Up Counter is set to 8 and is programmed to detect every occurrence of a 5 Volt pulse. When it has detected 8 such occurrences, the NO Contacts close and the NC contacts open.

5.11 Functions of controllers

- Great for making Real-Time Clocks, etc
- on-off control,
- sequential control,
- feedback control, and
- motion control

Direct Torque Control (DTC) significantly increases pull and drags forces and provides greater performance and constant power capability. Because of the high requirements of low harmonics (Voltage THD <5 %) and the voltage fluctuation of a weak grid, an active rectifier solution was used. In addition, when lowering the bucket, recovered braking energy is returned to the network. All drives and other devices are controlled by a PLC based system.

Benefits

- Higher reliability and lower maintenance costs
- Lower losses in drive system, saving 1,2 MWh/year
- Lower dynamic load – longer lifetime for gearbox and ropes
- 1–3 seconds shorter working cycle – 2–4% higher productivity
- 15 years longer lifetime for total dragline

5.12 Alarm System

Alarming allows for exception based reporting on events desired by programming of PLC. Alarms system can only be built on information sets contained in PLC in different parameter of dragline such as hoist motor, hoist generator, swing motor, swing generator, drag motor generator set, propel M-G set, fan, blower and lighting system of dragline. Alarms can't be changed without changing underlying PLC code.

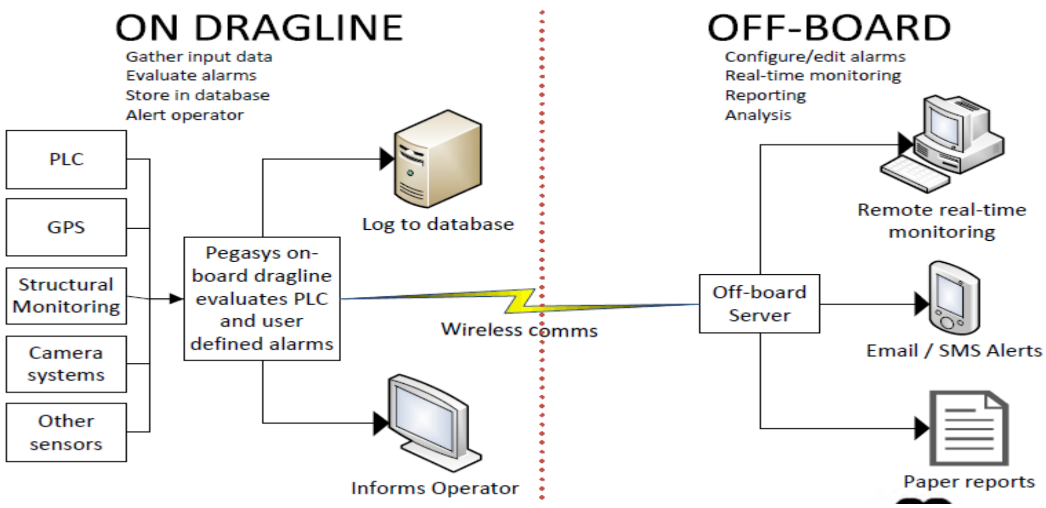


Fig: 5.5 Alarm system of dragline with diagnostic system

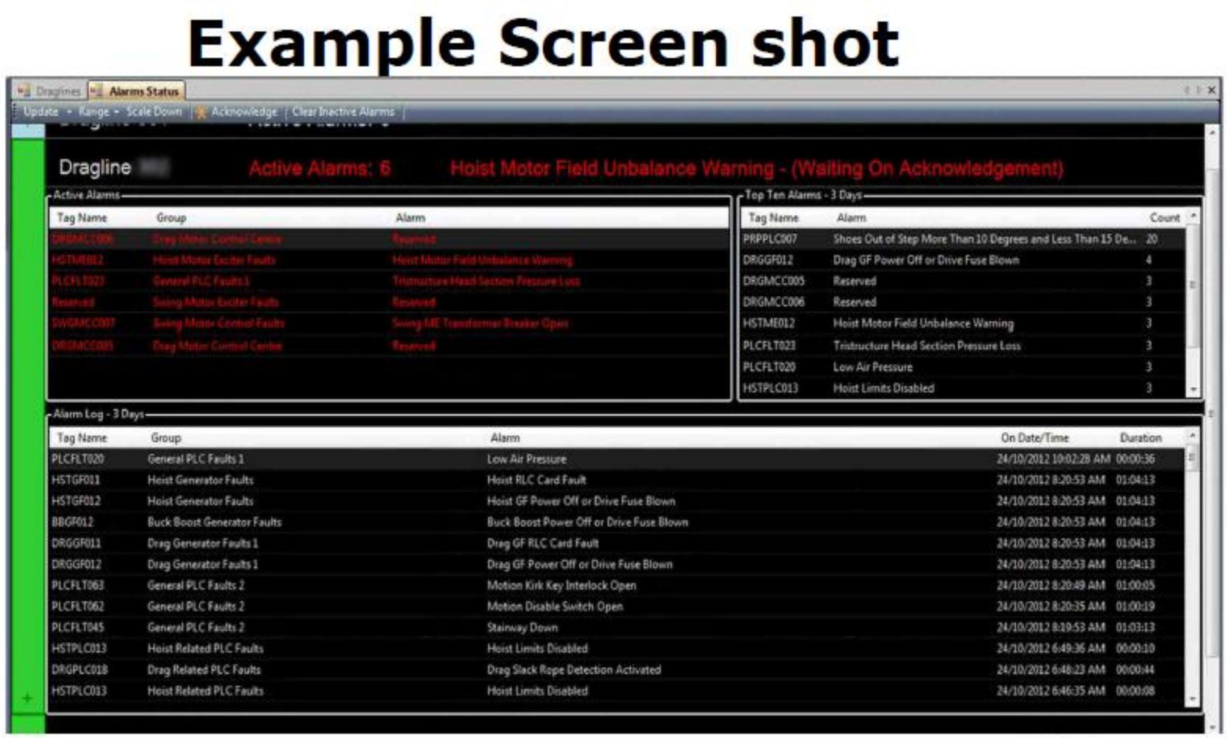
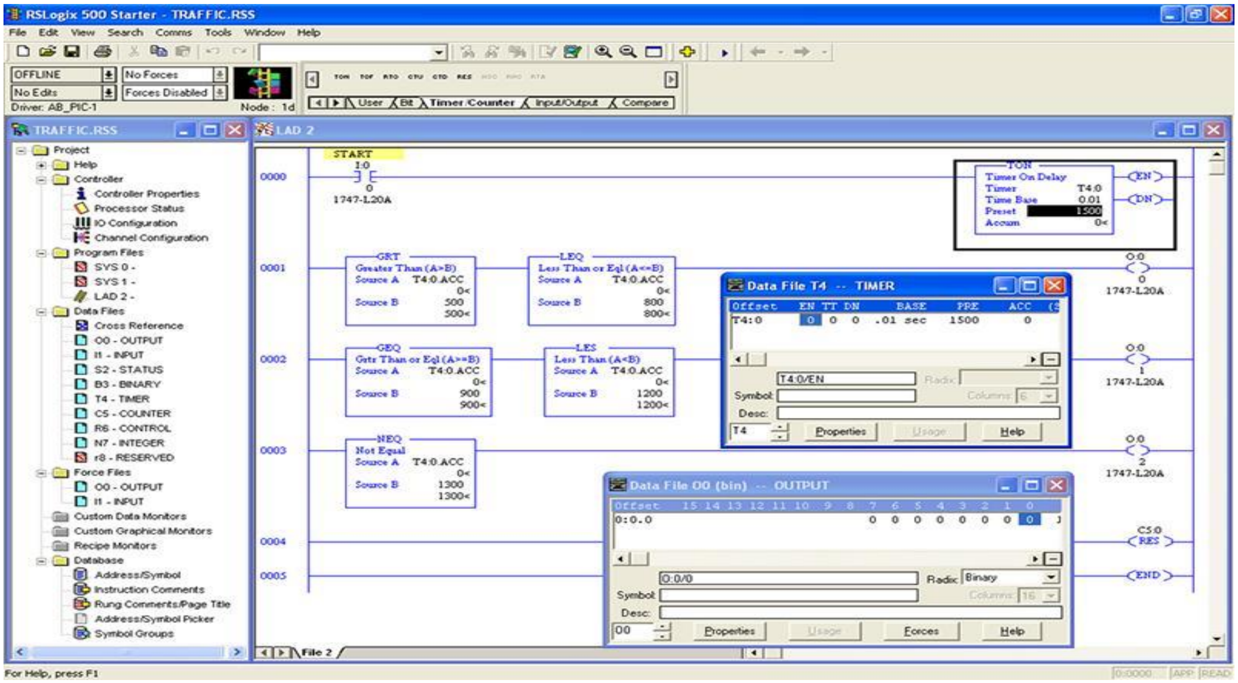


Fig: 5.6 diagnostic screen of dragline



Fig; 5.7 PLC Software (RSLogix 500) - Commercial

5.13 Integrated Support Centers (ISCs)

This has allowed some operations to go far beyond the basic production style report, and hence, are able to make more informed decisions. In addition, coupling these tools with high-speed Internet services between mine sites has further created an environment where multiple machines and sites can be monitored in real-time from anywhere in the world.

Integrated Support Centres (ISCs) provide:

- Leveraging capability to get more out of key content experts
- Better collaboration between personnel and sites across organizations and continents
- Greater standardization, compliance, and predictability of operations
- Faster response times to issues
- Better deployment of company resources based on more holistic views of the entire operations and its priorities
- Improved benchmarking accuracy across different operations
- Ultimately, reduced cost and improved financial, safety, and environmental performance

The establishment of the ISC required the following components:

- Ethernet based monitoring equipment and sensors that are capable of being remotely accessed, monitored and configured.
- Establishing correct routing and security profiles to make data available off-board the

machine

- Providing sophisticated data propagation technologies for data and vision systems to reduce network bandwidth loads
- Creating site-to-site VPN network bridges to connect the ISC to corporate client networks, and to the individual machines
- Leveraging from VOIP technologies.

The ISC allows:

- Leveraging of our key product experts and dragline/ shovel experts to resolving issues
- A proactive and faster response times to incidents
- Better standardization between our installations
- Greatly enhanced visibility of the performance and reliability of our equipment
- Significantly improved ability to deploy company resources to the best result for end users.

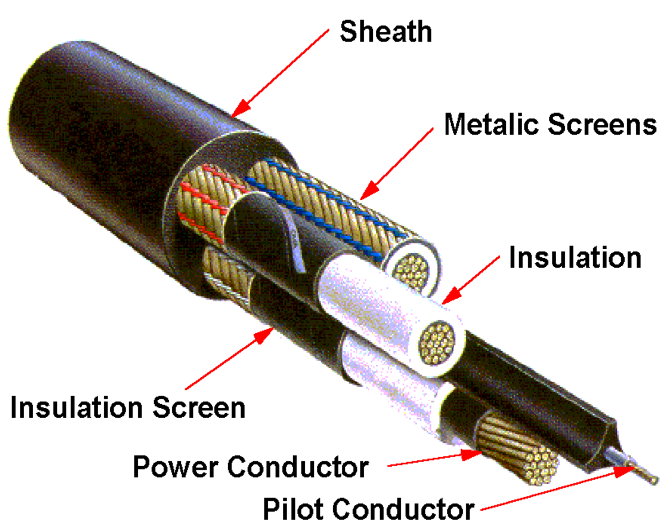
Chapter 06

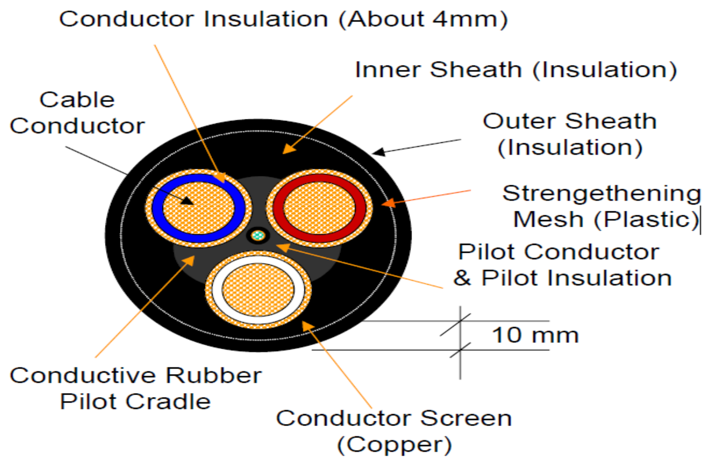
TRAILING CABLES OF DRAGLINE

6.1 Construction Trailing Cable

The high voltage trailing cable used to supply the electrical power of dragline. Main components of the trailing cable and their function is given as:

- Conductor of cable; Stranded Copper and bundled conductor are used that deliver the electrical power to the dragline. Area of conductor about 120-mm sq. and diameter is about 15.6mm.
- Insulation of Power Conductor; insulating material used in rubber compound designed to withstand high voltage about (6.6kv).
- Separator Cradle; A cradle separator that carries the pilot wire in the center of power conductor. In power conductor design having hole in center of conductor.
- Metallic Screens; each conductor is surround by earth metallic screens completely and carry the fault current when any type of fault occur in the cable.
- Pilot Wire;. Pilot wire used in protection of cable by used in relay to detect the fault in the cable.
- Sheath; sheath having used hard wearing material, tough durability, designed to separate the external environment from the conductors and able to withstand the physical, chemical, environmental, weather condition.
- Semi-conductive tape: tape to be used to separate the insulation from the conductors when the rating of the cable is greater than 3.3 kv.





Fig; 6.1 Trailing Cable having Construction voltage rating 6.6 kv, diameter 100mm

6.2 Potential Hazards

Trailing cable associated with Potential hazards due to following:

- Uncontrolled release of energy: dragline having operating voltage 6.6 kV used trailing cable could typically contain enough amount of energy to light 112,000, 40W light bulbs they are occur mainly due to,

    (i) Open arcing of cable caused by insulation failure
    (ii) Explosion of equipment due to rise of pressure inside the apparatus caused by insulation failure (plugs) of cable.

- Indirect contact: when person touch the outer sheath of a cable they are shock of electrically because cable energised under fault conditions. In fault condition current will be very high.
- Fire –under fault condition cable catches fire and equipment near the cable or surrounding environment also catches fire.

6.3 Recommendations

Standards operation of trailing cables is defined as,

- Regular testing of trailing cables is defined the life cycle criteria, measure and minor fault condition, maintenance of test records of monthly, daily
- Route test of trailing cable defined the criteria including support system measures where it's applicable, methods of crossings, heights, location, vehicle crossings, protection measures the requirement of cable where it is necessary to swing the cable over the top.

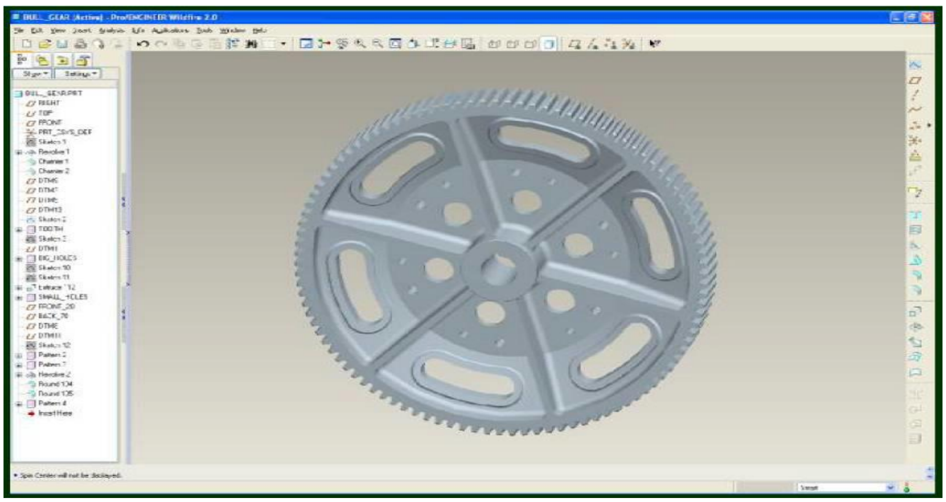
Chapter 07

COMPUTER AIDED DESIGN, MODELLING AND ANALYSIS OF BULL GEAR OF A DRAG LINE

7.1 Modelling Procedure of Bull Gear

Modeling and drafting of bull gear is done in pro-e software. The various tools used for modeling of bull gear is revolve, extrude, chamfer, round, pattern. Various steps in modelling are as follows:

- Sketch dedendum circle and then extrude.
- Sketch the one teeth profile and then extrude.
- Pattern the teeth.
- Sketch one arm of gear and then extrude.
- Pattern the arm.
- Sketch the one hole.
- Pattern the holes.



Fig; 7.1 Modelling of Bull Gear

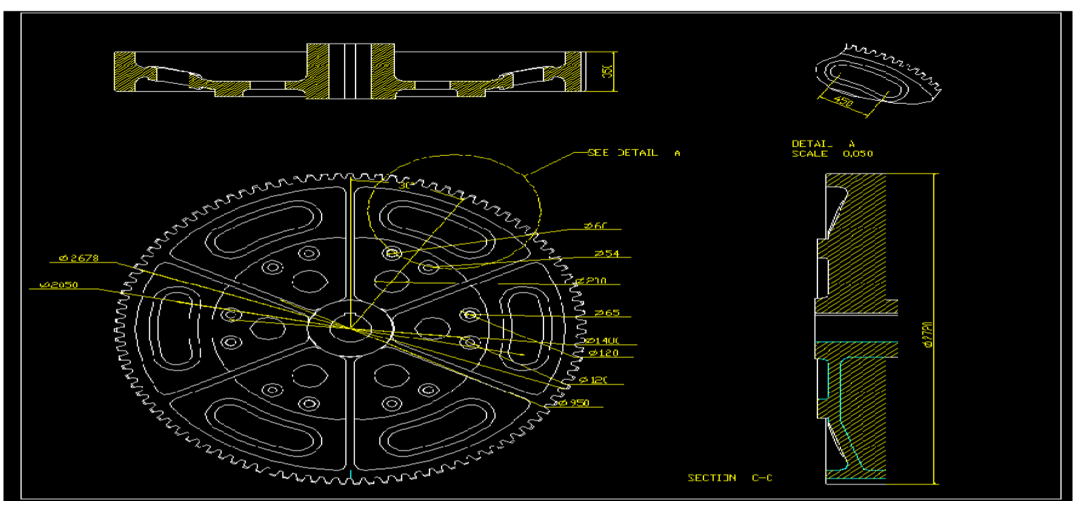


Fig: 7.2 Drafting of Bull Gear

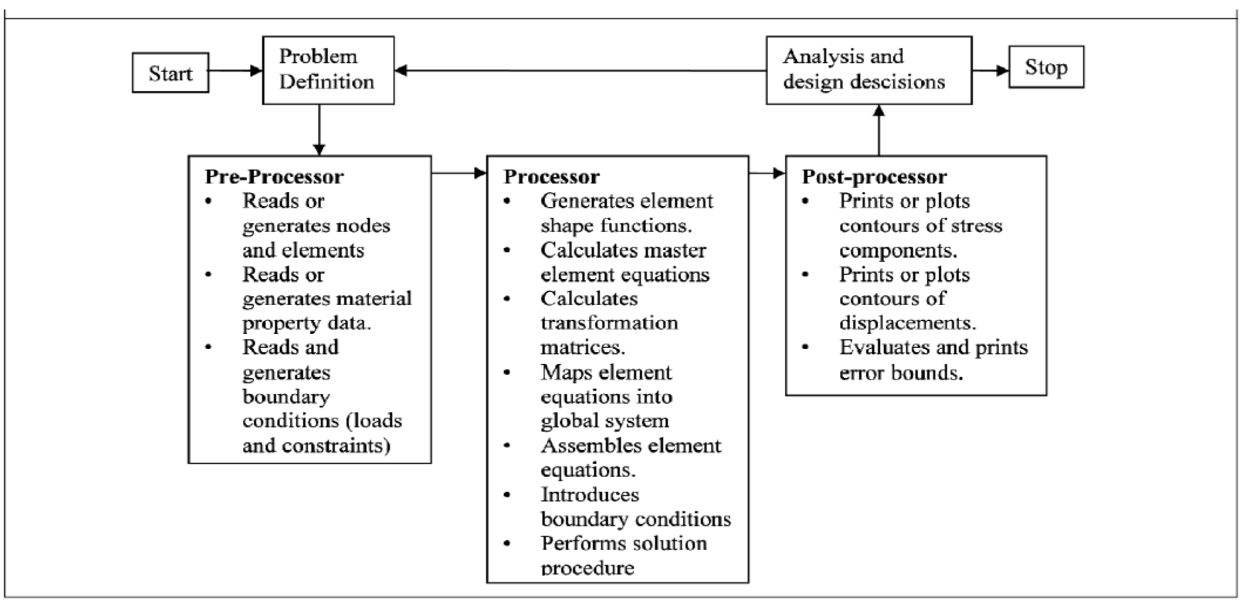
7.2 FINITE ELEMENT APPROACH

Finite Element Methodology

Finite element method always follows a step by step process. The process is given as,

Step 1: Discretization of the Structure of the modal.
Step 2: Selection of Displacement Model or Proper Interpolation.
Step 3: Derivation of the Element Stiffness Load Vectors and Matrices
Step 4: Overall Equilibrium Equations by Assemblage of Elemental Equations.
Step 5: Solution for the Unknown Nodal Displacements solution is obtain.
Step 6: Elemental Stress and Strains is commutated.

The general steps followed in a finite element analysis with a commercial FEM package is as shown below:



Fig; 7.3 Computer Aided Modeling of Bull Gear

7.3 Rigging mechanism

Dragline bucket is mounted on the boom with supporting wire ropes. Bucket movement depend on the number of ropes and chains, it is called rigging mechanism. This mechanism mainly consist of the ballasts the bucket. Also, wire ropes support the horizontal and vertical movements of the bucket of the dragline. Bucket and rigging mechanism classified into four groups:

- Optimization of bucket filling of dragline
- Testing of bucket kinematically
- Improvement of rigging system
- Automation of the scooping.

Data from Dragline Abhimanyu dragline 24/96, NCL Singrauli Amlori Project different part of bucket is given as,

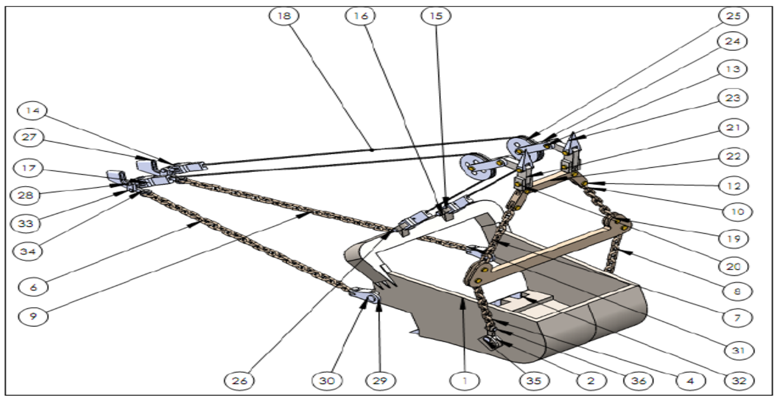


Fig: 7.4 Elements of Dragline Bucket and Rigging Mechanism

Table 7.1 part of dragline bucket

Item Number	Part Number	Quantity
1	Bucket Main Body	1
2	Trunnion Link	2
4	Chains (Hoisting, Right Lower Side)	9
6	Chains (Dragging, Right Side)	29
7	Chains (Hoisting, Right Upper Side)	9
8	Chains (Hoisting, Left Lower Side)	9
9	Chains (Dragging, Left Side)	29
10	Chains (Hoisting, Left Upper Side)	9
12	Pin (Spreader)	8
13	Pin (Hoist Shackle and Sheave)	8
14	Pin (Dump Socket)	4
15	Dump Rope Socket	4
16	Connecting Link 1	2
17	Connecting Link 2	4

18	Wire Rope	2
19	Lower Spreader	1
20	Hoist Link	2
21	Hoist Shackle	2
22	Upper Spreader	1
23	Rope Socket	2
24	Sheave Retainer	2
25	Dump Sheave	2
26	Pin (Connecting Link)	2
27	Drag Dump Link	2
28	Pin (Drag Dump Link)	2
29	Connecting Link 3	2
30	Pin (Connecting Link 3)	2
31	Pin (Connecting Link 3-2)	2
32	Tooth	6
33	Pin (Drag Dump Link 2)	2
34	Pin (Connecting Link 4)	2
35	Pin (Trunnion Link)	2
36	Pin (Trunnion Link 2)	2

7.4 Finite Element Analysis (FEA) of dragline bucket

FEA is a computerize simulation technique which are used to analyzed the physical condition such as strain & stress, displacement, force, acceleration, velocity, mass of solid body, using to identified the numerical value, called finite element. FEA drives a point's called node. Node having complex configurations and it generates adjoining grids called as mesh. Mesh is a network where adjacent node is connected to each other. Structural analysis in FEA contains nonlinear and linear models. FEA are used in dragline bucket to analyze the interaction that is mostly affected by formation specifications such as internal friction angle, density, external friction angle, adhesion and cohesion.

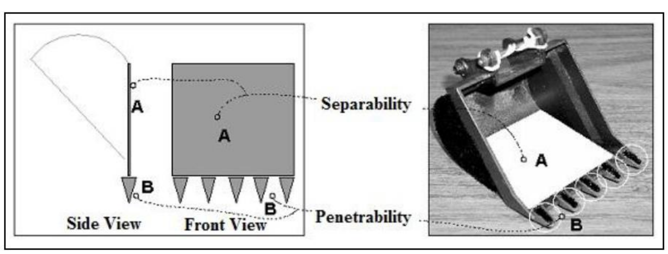


Fig: 7.5 Penetration and Separation Parts of a Bucket

An earthmover performs of dragline having main earth digging mechanisms are penetration & cutting. Dragline bucket mainly consists of two parts, a rectangular shape floor component of bucket called separation plate shown in figure A. With the help of this plate, a bucket of dragline is able to move the overburden by pushing or dragging (dragline bucket). Secondly, the bucket having another mechanical component which is called teeth, shown in figure B. Bucket teeth penetrate the overburden material to release digging mechanism. In a dragline combination of rope and chain gives the axial motion of the bucket and also determine the digging direction of the dragline bucket.

The bucket of the dragline firstly penetrates overburden with the help of own weight of bucket and cut it along the operating direction of dragline. In dragline required to estimate resistive forces against to provide the stress distribution on the tool and to limit the earthmover torques and velocity which are necessary for an efficient operation. In empirical formula (equation) of the cutting conditions and geometry of the digging tool is given as,

$$P = 10C_0 e^{1.35}(1 + 2.6b)(1 + 0.0075\alpha_c)(1 + 0.03s)\alpha_0 k$$

Where,

C_o = coefficient of compactness,
α_0 = coefficient of tip angle,
s = width of bucket in m,
k = coefficient of cutting-type.
P = cutting resistance,
b = cutting depth in cms,
α_c = angle of cutting in degrees,

7.5 Cutting Resistance Models (Analytical Approaches)

In this models which are divided into three main categories according to the earth-moving activities, cutting, penetration, and loading of bucket. Draglines used to removal of overburden consist of dragging, hoisting, and swing functions. Resistive force models shown in different condition.

The resultant cutting force is given by the Equation

$$T = w\left[\left(0.5\gamma t^2 tan^2(45 + 0.5\rho)d_1 + \frac{e^{2w'tan\rho}-1}{4\,tan\rho} r_0{}^2\gamma d_2 + qttan^2(45 + 0.5\rho)d_4\right)d_3{}^{-1} + \left(0.5(r_1^2 - r_0^2)\frac{c}{tan\rho} + 2ct\,tan(45 + 0.5\rho)\,d_4 + \frac{qt}{sin(45-0.5\rho)}d_5 + C_a l d_7\right)d_6^{-1}\right]$$

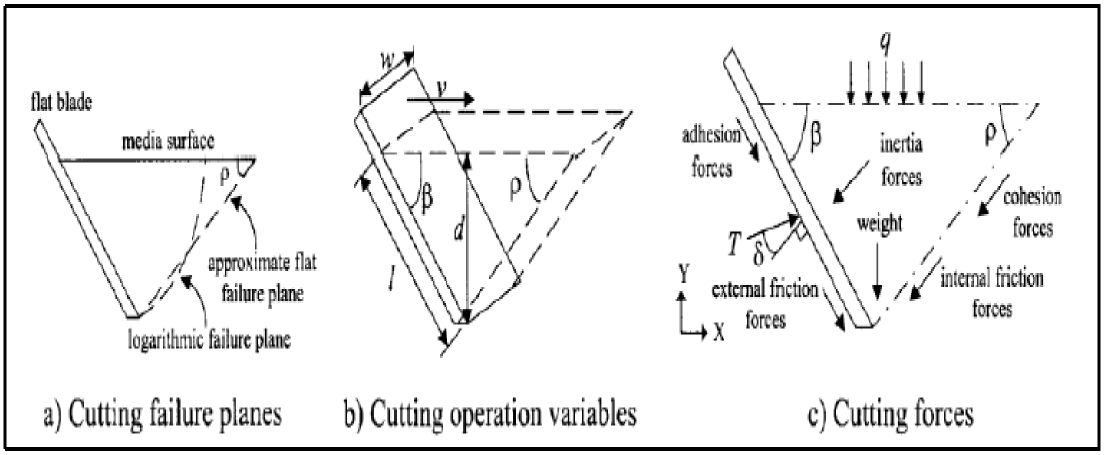


Fig: 7.6 Failure Plane in Formation Cutting

Where,

T = resultant cutting force of the dragline bucket,
d = tool depth,
Ca = adhesion,
p = angle of shear plane,
γ = specific weight of bucket,
ω = width of tool,
l = length of tool,
t = depth of Rankine Zone
c = cohesion,
r_o = radius of curvature, and d_1 $d_2 d_3$.....d_7 are graphical distances.

Resultant force cutting on the horizontal plane given as,

$$H = T sin(\beta + \delta)$$

Where,

δ = external friction angle
β = cutting (rake) angle,
H = resultant horizontal force of cutting

Chapter 08

RESULTS AND DISCUSSION

8.1 Dragline balancing diagram of dragline

It is graphical representation of the area to be used for determine the suitable place of dragline position to be maximum overburden remove in that particular area with minimum rehandling is required to achieve high rate of coal extracted with minimum cost of production and make the slope stability of desired area. The balancing diagram of dragline determine the amount of coal expose by the dragline, the volume of overburden to be removed in the decoaled area percentage of overburden, rehandling height of bench, cut geometry width of cut seam thickness, slope angle, seam gradient etc.

8.2 Preparation of Dragline balancing diagram

Here shown in the diagram let us assume that, the dragline place on the highwall side removes the overburden having cross-sectional area of first-dig as shown in figure. Maximum overburden dump area A_2 is limited due to dump slope stability of dump area. Assuming swell factor (Generally 1.25) of the overburden material, hence actual area required for remove overburden to dump would be A_1S.

S = swell factor
A_1= First-dig area (area of BCDE)
A_2= Dump Area (area of FHKG)
A_3= A_1S-A_2
A_4 = area of coal (area ABCO)

Now

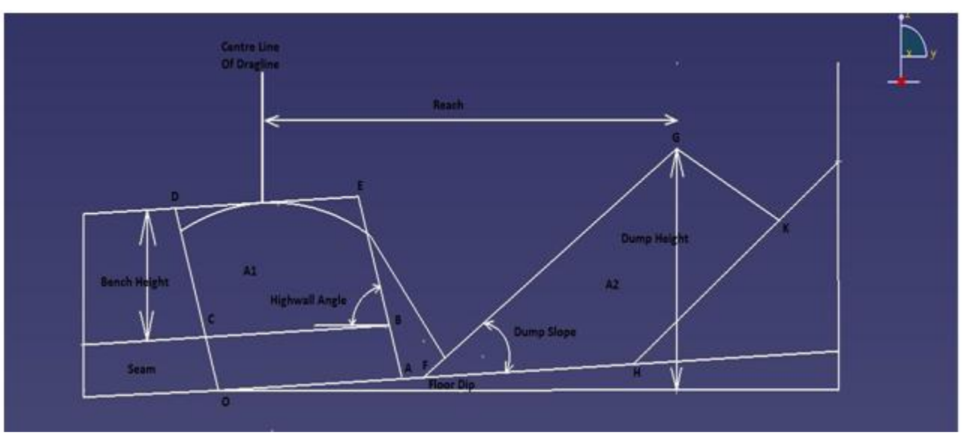


Fig 8.1: balancing diagram of Dragline

1. **Condition (A_3<0)**

In this condition dump area is not capable of accommodating OB more than the available first-dig quantity, hence overburden rehandling is required.

2. **Condition (A_3=0)**

In this condition indicates an optimum solution (balance condition) of overburden removal and in this condition having maximum coal expose with minimum cost. In this condition no overhandling is required.

3. **Condition (A_3>0)**

In this condition dump area is not capable to taking the loose material of first-dig completely and A3 amount of overburden material would be left as residual. This residual material can be removed by two ways,

- Transporting of dump material and dump to another place by using dumper.
- Extra dump capacity generating this can be increased by increasing reach. In this condition Extended bench method are used.

8.3 Calculation of annual output, operating cost, ownership, and cost per tonne of coal exposed in dragline in Amlori project NCL Singrauli open cast mine.

Estimating Dragline Production

A basic approach to estimating the dragline production of **Amlori project NCL Singrauli open cast mine** use of a standard cycle excavator equation that are used to calculate monthly dragline output is,

$$O = \frac{B \times BF \times HS \times A \times J \times 3600}{(1+S) \times C \times (1+R)}$$

Where,
O= output (bcy/month)
B= bucket size of dragline (yd)
A= maintenance availability (%)
BF= bucket fill factor of dragline
HS= hour scheduled /month

S= swell factor of overburden material / 100
C= average cycle time of bucket (second)
R= rehandling percentage /100
J= job factor (percentage of time that stripping of overburden machine is available)

8.4 Evaluation of Availability (A) and Utilization (U)

To calculate A and U field data was required and maintained on day to day on the basis of dragline under study.

$$A = \frac{(SSH - (BH + MH))}{SSH}$$

$$U = \frac{(SSH - (BH + MH + ID))}{SSH}$$

Where,

SSH = scheduled shift hour
MH = maintenance hour
ID = idle hour
BH = breakdown hour

For, NCL Singarauli Abhimanyu Dragline (24/96)

SSH = 720, WH = 507, MH = 119, BH = 33, IH = 61

Standard cycle time (second) = 60 sec, Observed cycle time (second) = 61.7 sec

$$A = \frac{720 - (119 + 33)}{720}$$

$$= 0.7888$$

$$U = \frac{702 - (119 + 33 + 61)}{720}$$

= 0.7041

So, we get Availability = 0.7888

Utilization = 0.7041

8.5 Digging hours

If the dragline is operated one extra minute per shift, this equates 18.2 hrs/year =15,000m^3 extra production

Based on the observed data in Amlori Project NCL Singrauli, average cycle time, A and U annual output (P_0) of the dragline is given as,

P_0 = (B/C)* U *A* M*S*F*N_s*N_h*N_d*3600

Where,

B = Capacity of bucket (24/96) dragline (cubic meter)

C =Average cycle time of dragline (second)

S = Swell factor of overburden material.

F = bucket fill factor

M = machine (dragline) positioning and travelling factor.

N_s = No. of operating shifts in a day, generally 3 shift per day.

N_h =No. of operating hours in a shift, generally 8 hour per shift.

N_d =No. of operating days in a year.

Above equation the calculation of output put the value of average cycle time (C), A and U are used field observations of Amlori Project NCL Singrauli open cast mine. Remaining factors are CMPDI in regard to the values of these factors in Indian coal mines are to be used.

Table: 8.1 Productivity factors for dragline as per CMPDI recommendations

Particulars	Recommended values
Swell factor (S)	0.719
Fill factor (F)	0.733
Machine travel and positioning factor (M)	0.8
No. of shifts in a day (N_s)	3
No. of hours in a day (N_h)	8
No. of days in a year (N_d)	365

For, NCL Singarauli Abhimanyu Dragline (24/96)

P_0 = (24/61.7)* 0.719*0.555*0.8*0.733**8*3*365*60*60
= 2.80 M cu.m.

So, the annual output of Abhimanyu dragline in Amlori Project NCl Singrauli is 2.80 M cu.m.

8.6 Computation of Efficiency of Draglines

The efficiency of dragline was calculated by using the following formula.

$$\text{Efficiency of dragline}(\eta) = \frac{\text{Computed annual output}(P_1) \times 100}{\text{Annual output as per the balancing diagram }(P_2)}$$

The determine the annual output of dragline it is necessary to prepared the balancing diagram of horizontal tandem and vertical tandem modes of operation of dragline, respectively

8.7 Calculation of Coal Exposure of dragline

The total coal expose by the draglines working in different tandem mode of operation was estimated by generalize the balancing diagram concept.

$$\text{CE} = (P_{\text{FD}}/A) \times W \times T \times D \times R(\text{M te})$$

Where,

CE = Coal exposure of dragline (M te),

PFD = lagging dragline of annual output from the first dig (Mm^3),

A = area of first dig (m^2),

T = coal seam thickness (m),

W = cut width of dragline (m)

D = specific gravity of coal to be extracted,

R = recovery factor.

The term (PFD/A) represents the annual linear advance of the draglines

8.8 Estimation of Operating Cost

The Cost calculation has been made on the basis of information supplied by **NCL Singrauli Amlori Project.**

Approach to the problem

No. of annual working day- 300

No. of daily shift- 3

Duration of each shift- 8 (hour)

No. of operators for dragline in each shift- 2

No. of helper- 1

Oilers, Electrician and Mechanics are including in maintenance cost.

Calculation of Operating Cost and Ownership of Abhimanyu dragline in Amlori project NCL Singrauli,

1. **Cost of Ownership per year of 24/96 dragline**

(a) Equipment Cost

Cost of Abhimanyu dragline (24/96) = Rs.160 crore

(b) Depreciation Cost of Abhimanyu dragline 25 year i.e. annual flat rate of 4%

Annual depreciation cost of Abhimanyu dragline (24/96) = Rs. 6.4 crore

(c) **Annual Cost of Ownership of dragline**

Average annual investment of Abhimanyu dragline

$= \frac{N+1}{2N} \times$cost of Abhimanyu dragline

$= \frac{25+1}{2\times25} \times 160$ crore

= Rs. 83.2 crore

Where N = Life of dragline

(d) **Insurance, annual interest, and taxes of Abhimanyu dragline i.e. annual flat rate of 12.5%**

= 12.5 % of Rs. 83.2 crore

= Rs. 10.4 crore

Hence, Total Ownership Cost per year of **Abhimanyu dragline** = [depreciation cost per year + annual interest, insurance and taxes]

=Rs. **[**6.4 **+**10.4**]** crore

= Rs. 16.8 crore

2. **Operating Cost per year of Abhimanyu dragline (24/96)**

(a) Annual Manpower Cost of Abhimanyu dragline (Salary & Wages)
Operator Cost @ Rs. 0.02 crore/operator for 2 operators in 3 shift = Rs. 0.12 crore
Helper cost @ Rs. 0.01 crore for 1' 3 = Rs. 0.3 crore
Hence, Total Manpower Cost = Rs. (0.12 + 0.03)
=Rs. 0.15 crore

(b) **Annual energy and power consumption on the basis of 13.65 MKWH**
Annual power consumption cost @ Rs. 4.89/KWH
Rs. 4.89×13.65 MKWH
Rs. 6.675 crore

(c) **Annual lubrication Cost Abhimanyu dragline**
Annual lubrication cost @ 30% of cost of consumption Abhimanyu dragline
= Rs. 2.0025 crore

(d) Annual Maintenance Cost

Annual maintenance cost of Abhimanyu dragline @ 20% of depreciation cost = Rs. 1.28 crore

Major breakdown maintenance cost @ 2% of cost of equipment = Rs. 3.2 crore

Total maintenance cost of Abhimanyu dragline = Rs. 4.48 crore

Hence, Total annual Operating cost of Abhimanyu dragline = Rs. [0.15+ 6.675+ 2.0025+ 4.48]

= Rs. 13.3075 crore

Total annual ownership cost and operating cost

= Rs. [16.8+ 13.3075] crore

= Rs. 30.1075 crore

Considering annual output of 24/96 dragline as 3.4Mm^3

$$= \frac{30.1075 \text{crore}}{3.4\ \text{Mm}^3}$$

= Rs. 88.55 per/ m^3

Calculation of cost per tonne of coal exposed of Abhimanyu dragline

1. **Single dragline Operation without rehandling**

Amount of effective overburden handled = 3.4 Mm^3.

Amount of coal exposure =

$$= \frac{\text{Annual production of dragline}}{\text{Avearge stipping ratio}}$$

$$= \frac{3.4\ \text{Mm}^3}{2.5\ \text{m}^3/\text{te}}$$

= 1.36 Mte

Estimated Cost per tonne of coal exposed =

$$= \text{Rs.} \frac{30.1075 \text{ crore}}{1.36 \text{ M te}}$$

= Rs. 221.37/te of coal exposed

2. **Single dragline extended bench operation**

Percentage of rehandling is 61.23%

Total O/B handle = O/B directly exposed coal + O/B rehandled

= O/B directly exposed coal (1+ coefficient of rehandled)

Here, Coefficient of rehandling is

$$= \frac{\text{O. B. rhandle}}{\text{O. B. removal to expose coal}}$$

Therefore, 3.4 Mm^3 = O/B directly exposed coal, 1.61

Hence O/B directly exposed coal removed by the dragline = 3.4/1.61

= 2.11 Mm^3

Amount of effective O/B handled = 2.11 Mm^3

Amount of coal exposure =

$$= \frac{2.11 \text{ Mm}^3}{2.5 \text{ m}^3/\text{te}}$$

= 0.844 Mte

Estimated cost per tons of coal exposed =

$$= \frac{30.1075 \text{ crore}}{0.844 \text{ M te}}$$

= Rs. 356.72 per tonne of coal exposed

3. **Horizontal Tandem Operation**

When leading and lagging dragline is deployed 24/96 having annual production of 3.4

Mm^3 each

Total Ownership and Operating cost per year of two dragline (24/96 + 24/96)

= Rs. 60.215 crore

Estimated cost per tonne of coal exposed in tandem dragline operation on the basis of average stripping ratio 2.5 m^3/te

Percentage rehandling is 42.48%

Amount of effective O/B removed = 6.8Mm^3/ 1.425

= 4.77Mm^3

Amount of coal exposed = 4.77Mm^3/2.5 m^3/te

= 1.91Mte

Estimated cost per tonne of coal exposed

$$= \frac{60.215\text{crore}}{1.91 \text{ Mte}}$$

= Rs. 315.26 per tonne of coal exposed

4. **Vertical Tandem Operation**

When the leading and lagging dragline having annual production 3.4 Mm^3

Percentage rehandling is 25.95%

$$Amount\ of effective O.B.\ handled = \frac{6.8 \text{ Mm}^3}{1.2595}$$

= 5.40Mm^3

$$Amount\ of\ coal\ exposed = \frac{5.40\text{Mm}^3}{2.5 \text{ m}^3/\text{te}}$$

= 2.16 Mte

Estimated cost per tonne of coal exposed =

$$= \frac{60.215 \text{ crore}}{2.16 \text{ M tel}}$$

= Rs. 278.77 per tonne of coal exposed

Hence, different mode of operation of dragline and estimated cost calculate.

8.9 Formula of maximum depth that can be worked by a dragline is given

$$\text{Maximum depth that can be worked by the dragline (H)} = \frac{t + \tan x\,(R - W/4}{S + \tan x / \tan y}$$

Thickness of coal seam in Amlori mine in working (t) = 4.5 m

Repose angle of overburden (x) = 38^0

Dragline Reach of (R) = 73 m

Swell factor of overburden material (S) = 1.39

Cut width (W) = 60 m

Slope angle between horizontal to highwall (y) = 70^0

$$\text{Maximum depth that can be worked by the dragline (H)} = \frac{4.5 + \tan 38\,(73 - 60/4)}{1.39 + \tan 38 / \tan 70}$$

H = 29.74 m

So, the maximum depth in that work is done = 29.74 m

8.10 In the given data of Abhimanyu dragline (24/96) in Amlori Project NCL Singrauli , after calculation we get

Percentage of Availability of dragline = 78.88 %
Percentage of Utilization of dragline = 70.41 %

And the maximum depth in that work is done = 29.74 m
The annual output of dragline = 2.80 M cu.m.

Table 9.1 Estimated cost of dragline in different mode of operation

S/N	Combination of dragline leading + lagging	Cut taken by leading dragline	Cut taken by lagging dragline	Mode of opration	Cost per tonne of coal exposed
1.	Abhimanyu dragline 24/96	All cut taken by single Abhimanyu dragline		Normal operation without rehandling	221.37
2.	Abhimanyu dragline 24/96	All cut and rehandling of over burden taken by single Abhimanyu 24/96 dragline		Extended bench method with rehandling	356.72
3.	Abhumanyu 24/96 + Akshay dragline 24/96	Key cut + first cut	First dig + rehandling	Horizontal tandem mode	315.26
4.	Abhumanyu 24/96 + Akshay dragline 24/96	Top cut + key cut	First dig + rehandling	Vertical tandem mode	278.77

Chapter 9

CONCLUSION

9. CONCLUSION

9.1 About PLC in future development in dragline

The digital control system has been fully integrated with an extensive machine diagnostics package and touch-screen controls to speed maintenance work, increase operation efficiency and reduce down-time. A separate digital control system with its own display is used to monitor all the different operation cycles including working time, number of cycles and buckets, walking time and steps, etc. 3rd generation production monitors included high precision GPS technology, used in conjunction with 3 dimensional mine plans to guide the dragline operator. Further development of this technology has provided products that cater to the needs of the wider mine site audience. This thesis described “production monitors” as “dragline monitors”, reflecting their use as both a production monitor, and also providing the context for the management of the maintenance aspects of the dragline. 4th generation dragline monitoring systems have made full use of this wireless infrastructure. Camera video and real-time streaming data from dragline monitoring system is now accessible through wireless infrastructure.

9.2 Drive system with PLC

A separate digital control system with its own display is used to monitor all the different operation cycles including working time, number of cycles and buckets, walking time and steps, etc. Temperature monitoring of motors and cooling air flux measuring is carried out. Electrical parameters as consumed and generated active power and reactive power are recorded. Reports for variable periods are produced. All information is transmitted wirelessly and archived to a common Scada system where it is possible to make productivity analysis and plans for service or repairing and data archiving.

- The digital control system has been fully integrated with an extensive machine diagnostics package and touch-screen controls to speed maintenance work, increase operation efficiency and reduce down-time.
- A separate digital control system with its own display is used to monitor all the different operation cycles including working time, number of cycles and buckets, walking time and steps, etc.
- Temperature monitoring of motors and cooling air flux measuring is carried out.
- Electrical parameters as consumed and generated active power and reactive power are recorded.
- AC upgrades of drive system will reduce total Cost of Ownership through energy savings, reduced maintenance costs, improved productivity, increased safety, and increased availability

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*** M.Tech Student, Mining engg. Dept. NIT Rourkela**

**** Associate Professor and Head of the Mining engg. Dept. NIT Rourkela**

नार्दन कोलफील्ड्स लिमिटेड
(एक मिनी रत्न कम्पनी)
अमलोरी परियोजना
पोस्ट - अमलोरी परियोजना
जिला सिंगरौली (म. प्र.) 486887
(एक ISO 14001, ISO 9001, OHSAS 18001 और SA 8000 प्रमाणित कम्पनी)
फोन न. 07805-278474, फ़ैक्स न. 07805-278474/278633/257510

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Tele No. 07805-278474, Fax. 07805-278474/278633/257510

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No. Aml/ Sr. Mgr (Plng.)/2014/2605 15th Aug'14

CERTIFICATE

This is to certify that Mr. **Atma Ram Sahu** s/o **Banshi Lal Sahu,** student of **National Institute of Technology Rourkela,** department of mining engineering, M. Tech, roll no. **213 mn 1498,** have done training of Dragline section of **NCL, Singrauli Block, Amlori** in duration of 12/08/2014 to 15/08/2014.

The conduct of Shri Atma Ram Sahu was good and he took keen interest during training period.

I wish him a very happy & prosperous life and bright career.

15/08/14

Sr. Manager (M)/Planning
Amlohri Project